FINAL REPORT

BENEFIT COST ANALYSIS OF WINTER MAINTENANCE LEVELS OF THE IDAHO TRANSPORTATION DEPARTMENT

Submitted to:

IDAHO DEPARTMENT ~~OF~~ TRANSPORTATION

ITD-RP #110 C

University of Idaho
Civil Engineering Department
Donald F. Haber, Umesh S. Limaye

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Abstract

This study is submitted as a phase one of an applied cooperative research project commissioned by Idaho Transportation Department to analyze benefits and costs associated with the winter maintenance activities. The objective of the research was to formulate a model, based on historic data, to predict costs and benefits associated with the winter maintenance. The model could then be used as a tool for setting winter maintenance standards. Cost is affected by steady-state and transient factors. A steady state model and six transient models - one for each district-were formulated to predict winter maintenance cost using multiple regression analysis. Although no quantitative model could be formulated to express fatalities and injuries because of insufficient data it was statistically shown that injury rate on road sections decreased with an increase in the level of winter maintenance. Benefits related to delay times, comfort and convenience were quantified using the stochastic simulation. A computer program was developed for use on a PC type computer to illustrate the simulation of benefits and prediction of costs associated with changes in winter maintenance levels for any specified road section.

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Chapter 1: INTRODUCTION

Setting the winter maintenance standards for different road sections is one of the toughest challenges for the Idaho Transportation Department. Any upgrade in current winter maintenance standards requires more resources (costs) which should be balanced against perceived benefits such as increased safety, decreased delay and user comfort/convenience. Current methods used by ~~IDT~~ ITD to quantify benefits and costs are based on assumptions which should be critically examined in light of new information. Using updated historical data, it may be possible to formulate more realistic costs and benefits of winter maintenance. The purpose of this study is to provide the Idaho Transportation Department with a benefit-cost model formulated from the most recent cost, accident, and delay time information.

Chapter 2: Background

The Idaho Transportation Department (ITD) has divided the state highway system into six geographic districts, each supervised by a district engineer and his staff. Each district is subdivided into five to seven foreman areas (FA's). There are 37 such FA's in the entire state. The physical boundaries of these foreman areas are shown in Map 2-1. Because of the difference in topography and the climate for FA's, characteristics of the road sections and the associated winter maintenance costs vary considerably among FA's. Each road segment is assigned a degree of winter maintenance or a level of service. Five such levels are defined and the maintenance standard for each level is specified (Table 2.1). Each FA is responsible to maintain assigned road sections at a designated level of service, during a winter.

Presently the level of service for each road section is set by a model which was developed from relatively old information. It determines a benefit/cost analysis associated with the level of service. Once the calculated benefit/cost ratio exceeds 2.0, the road section becomes a candidate for increased level of service. At this point, other factors like route continuity are considered subjectively, before a final decision is made.

The current procedure uses data gathered for each district on "Rural Icy or Snow Covered Accidents". The number of accidents, injuries, and fatalities, are used to predict average annual economic loss per mile. A comparison was made between the cost of keeping the roadway completely clear and the savings in reducing winter accidents by fifty percent. This analysis is based on following assumptions :

a. An upgrade in the level of service would reduce the winter accidents by 50%

b. Cost of material, labor and equipment required for sanding and clearing a lane-mile of road is $13.05 c.

c. A snow storm frequency of 0-15, 15-30, 30-45, 45-65, and over 65 would require a sanding frequency of 22, 45,70,90, and 100 times, respectively.

The main factors of the benefit/cost ratio are economic savings (ECONSAVE), economic loss (ECONLOSS), and the cost (COST). ECONLOSS is the total dollar cost of accidents per mile per year on the given road segment expressed in thousands of dollars. The "per year" is based on the 3 year average.

$$ECONOLOSS = (PDO * K1) + \frac{INJFAT * K2}{LENGTH * 1000}$$

PDO and INJFAT are respectively the number of property damages and injuries/fatalities reported on a particular road segment over 3 year period. K1 and K2 are the average cost values for property damage and injuries/fatalities, respectively. As upgrading the level of service reduces accidents by 50% ,

$$ECONSAVE = 0.5 * ECONLOSS$$

Cost per mile of road (in thousands of dollars) is determined by the equation:

$$COST = \frac{(13.05 * LANE * STORM)}{1000}$$

where, LANE is the number of lanes and STORM is the number of sandings required per year on the road segment. Benefit/cost ratio is the ratio of ECONSAVE to COST.

The validity of the assumptions made in this approach is in question, according to ITD management. There is not enough information to verify that accident rate reduces by 50% with an increase in the level of service. On the other hand there is not enough information to disprove it either. The cost factor of $13.05 per lane-mile is not constant all over the state, but it changes considerably between FA,s because of the changing topography and climate. The current cost equation determines the cost for level of service one. The costs for other levels of service are not formulated in the model.

As a result of these concerns, a decision was made to attempt to refine this approach by-

1. Developing a cost model for winter maintenance, similar to the winter complement model (1) developed previously.
2. Including the benefits gained by the decrease in delay time and discomfort with an increase in winter maintenance standard.

A cooperative research contract was awarded to the Civil Engineering Department, University of Idaho, to develop such a model. The objective of the research was to formulate a model to predict costs and benefits, associated with the winter maintenance; based on historic data; which can be used as a tool for setting level of service standards.

MAP 2-1

FOREMAN AREAS

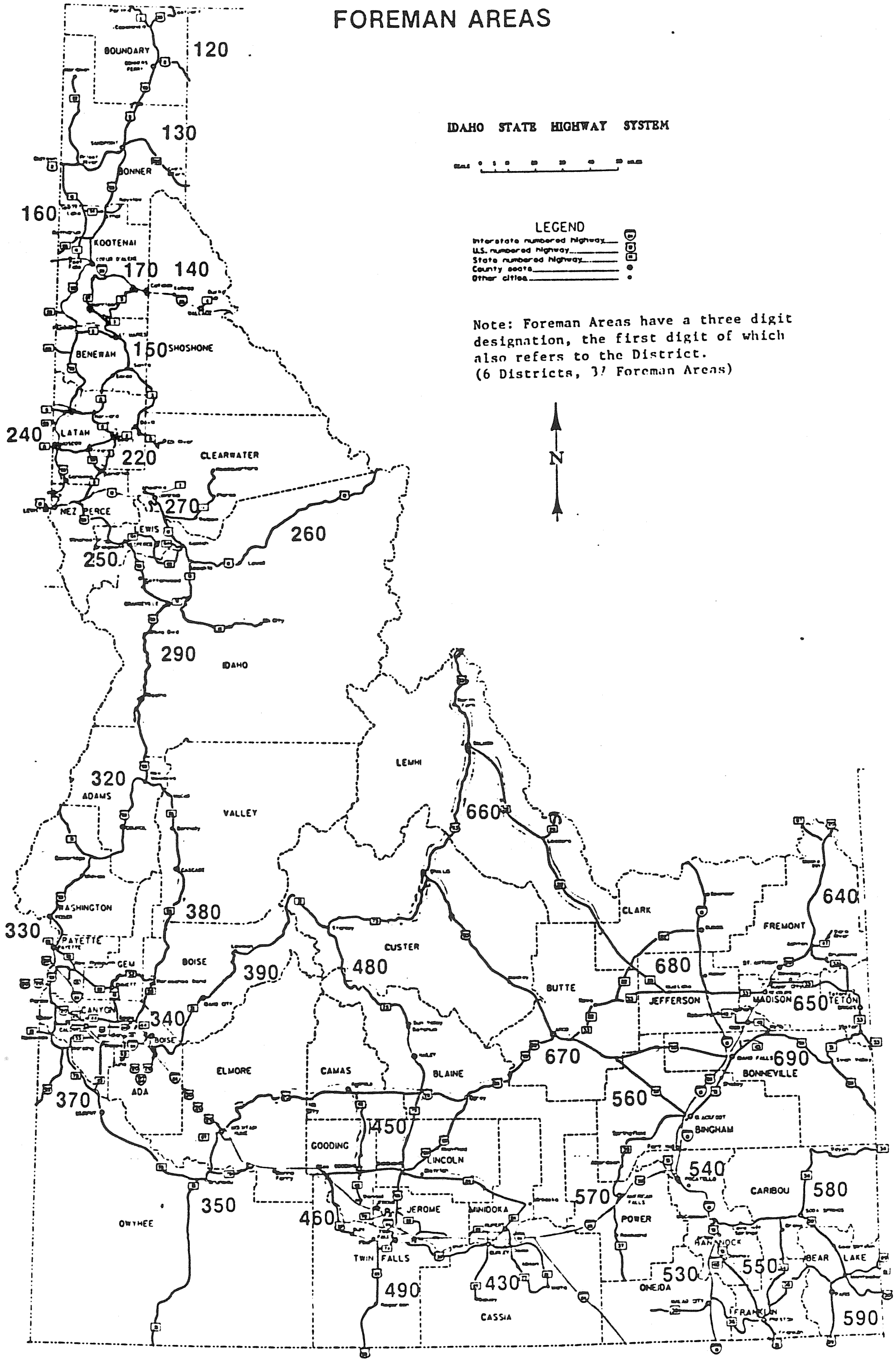


Table 2-1

Level of Service Definitions

Level of Service 1:
Remove snow continually during storms to keep the roads open to traffic and provide a reasonable surface on which to operate, except when blizzard, avalanche, or other severe forms of weather make conditions such that maintenance and motor vehicle operators cannot reasonably negotiate the travelway. Keep at least one lane in each direction open during the storm. Clear the remaining lanes and shoulders after the storm ends. Patrols may be established in the areas where surveillance is desirable. When effective, apply chemicals or abrasives, separately or in combination, to enhance traffic safety. Continue efforts until a trafficable condition exists.

Level of Service 2:
Remove snow during the storm to keep the roads open to traffic, except when blizzard, avalanche, or other severe forms of weather make conditions such that maintenance and motor vehicle operators cannot reasonably negotiate the travelway. Snowpack left by plows need not be removed until thawing conditions exist, or the pack becomes so thick as to constitute a traffic hazard when it thaws. Remove the pack and widen the travelway during regularly scheduled working hours, except that overtime may be authorized by the District Engineer if he determines it to be economically feasible. Patrols may be established in the areas where surveillance is desirable. When effective, apply chemicals or abrasives, separately or in combination, to enhance traffic safety on steep grades, sharp curves, bridge decks and approaches, intersections, known high accident locations, etc.

Level of Service 3:
When manpower and equipment are available, remove snow during the storm to keep the roads open to traffic, except when blizzard, avalanche, or other severe ~~for as~~ forms of weather m Eake conditions such that maintenance and motor vehicle operators cannot reasonably negotiate the travelway. Additional snow removal shall be accomplished during regularly scheduled working hours. Generally, chemicals and abrasives are not used, but may be applied at specific locations under unique and extraordinary circum~~-~~stances. These routes may be posted to indicate limited maintenance.

Level of Service 4:
Remove snow during the storm only when manpower and equipment are not being utilized to clear other routes. These routes m~~n~~ay be closed for an extended period of time until resources are available to plow the travelway. Winter Maintenance shall be accomplished during regularly scheduled working hours on these routes. Chemicals and/or abrasives are not used; if the surface condition becomes too hazardous for traffic to reasonably negotiate, the section should be closed. When temporary closures are required, signing, notification of authorities, etc., are accomplished in accordance with the Maintenance Manual. These routes will be posted to indicate limited maintenance.

Level of Service 5:
Allow these routes to close during the winter. Reopen in the spring when it is reasonable to assume that there will be no more snow storms. Signing, notification of authorities, etc., are accomplished in accordance with the Maintenance Manual. (Note: The state highway system has contained no Level of Service 5 routes since the 1985-1986 winter season.)

Chapter 3: Literature Search

Quantifying benefits and costs is certainly not unique. The first major application of benefit cost analysis was found in the flood control act of 1936. Today, benefit cost analysis plays a major role in public work projects in all fields. Before the modeling work began, an extensive literature survey was conducted on the quantifying of benefits and costs of winter maintenance levels.

From this search, two were of particular interest and both dealt with economic analysis of snow and ice control. The first was a study conducted by Ohio State Department of Highways (2), and the second was done by Utah Department of Transportation and was sponsored by Federal Highway Administration (3,4).

Ohio State Department of Highways (2) used data for three years to develop regression equations to predict the cost for snow and ice control in each county based on 30 years of average snowfall data and current average daily traffic (ADT) values for each county.

The study indicated that the two most significant independent variables affecting cost per lane-mile for snow and ice removal were depth of snowfall and ADT. The coefficient of multiple determination (R^2) varied from 0.36 to 0.64 for different counties.

Utah Department of Transportation (3,4) conducted a detailed three phase study to develop an economic model that performs benefit cost analysis. The economic analysis was based on procedural, material, environmental, delay, comfort, convenience, facility damage, and safety considerations. The model was developed using the information obtained through field data collection. Economics of Snow and Ice Control (ESIC), the computer program, was written in FORTRAN and contained five modules - Maintenance, Traffic and Safety, Environmental, Structural deterioration, and Vehicle corrosion. Though this model considers benefits and costs in detail, an enormous amount of data is required to run the model. The model is based on data collected from several states and its applicability to just one of those states may be questioned.

Although these publications and several others dealt with economic analysis of snow and ice control, there were enough differences that direct application of these methodologies to Idaho roads was limited.

Chapter 4: Methodology

The objective of this project was to develop a benefit cost model, using the historical data, which could be used as a tool for setting the winter maintenance standards. Because of the nature of data available and the difference in the ways costs and benefits accrue; two different approaches were used to obtain costs and benefits.

- Costs

Material, labor, and equipment costs for all maintenance activities are recorded on a ITD database, and were available. Costs were to be expressed as function of primary significant factors affecting cost. Multiple regression analysis is a well suited approach for this type of problem. It is a statistical tool that identifies a statistical relation between a variable (" dependent or response variable") and a set of variables ("independent or predictor variables").

Given a set of variables, multiple linear regression will estimate the values of coefficients (b_i), for each independent variable (x_t) and also the intercept (b_o).

Knowing these values a regression equation (often called as response surface) of the following form can be estimated.

$$E(Y) = b_o + b_1 X_1 + b_2 X_2 + \ldots + b_i X_i + \ldots + b_n X_n$$

The coefficients (b_i) indicate the slope of this response surface, partial to the respective independent variable.

As a first step towards the development of a cost model, candidate independent variables or the possible factors that may affect cost were identified. Some of these factors were time dependent (transient factors) while the others remained essentially constant over the time period (steady-state factors). As they can not be combined together to form a single model, a two stage approach was used. Two separate models were developed. One expressed the average cost over the time period as a function of steady-state factors. The other model correlated yearly deviations from the average cost, predicted using the previous model, to the transient factors.

- Benefits

Benefits of maintenance are realized in several ways. In this project, potential benefits resulting from reduction in accident rates those related to delay times, comfort and convenience were investigated.

Winter related accidents that occurred on the Idaho state highway system from 1983-1989 are recorded on a database. During this period, the level of service on a very limited number road sections was changed. Using the information from the data relating to these specific road sections, a regression analysis was attempted to correlate change in accident rate with change in level of service.

Stochastic simulation was used to quantify the delay times. Delay depends on vehicle speed which can be modelled using a probabilistic distribution of snow speed and dry road speed. As the delay is inversely proportional to snow and dry road speed, the expression for the probability distribution of delay becomes highly complex and it is virtually impossible to solve mathematically. In such a situation, numerical, computer based simulation is an alternative. The simulated delay times were then transformed to a monetary value. Discomfort costs were treated as the function of delay. For this, transformation functions developed by Utah Department of Transportation were modified and used.

A substantial portion of the information used in this model development was obtained from ITD's databases. As a result, a large percentage of this project involved data queries, manipulation and general database management. Statistical Analysis System, commonly known as SAS, was used for data handling and statistical analysis. SAS regression procedures like STEPWISE and REG helped researchers with selection of different variables while analyzing, testing, and refining the models.

Chapter 5: Variables in The Cost Model

Independent variables are factors that may influence the dependent variable. Before multiple regression analysis can be started, the dependent and the independent variables must be identified. As a first step toward constructing a cost model, several factors that may influence costs were identified and computed. Many of these factors (those marked by an asterisk in the list below) were previously identified and defined by Haber et al (1) as the factors that influenced manpower. Material, equipment and labor costs can not accrue unless manpower is expended. Therefore, the factors that affect expenditure of manpower affect cost. These factors included :

STEADY-STATE FACTORS
- Road Factors
  - . Total lane-miles in the FA *
  - . Level of service factor *
  - . Winter traffic volume *
  - . Road curvature *
  - . Road gradient *
  - . Passing sight distance *
  - . Stopping sight distance *
- Terrain / Climatic Factors
  - . Terrain type *
  - . Elevation *
  - . Wind factor *
  - . Snow factor *
  - . Climatic region factor *
  - . Temperature *
  - . Average storm hours
- Transient Factors
  - . Storm frequency
  - . Statewide inflation index
  - . Total stormhours expended
- Dependent Variable
  - . Total average cost

These factors are grouped into two major categories; steady-state factors and transient factors. Steady-state factors are those that have remained practically unchanged over the time (1982-1989), while transient factors are those which change substantially from year to year.

STEADY STATE FACTORS

- Total Lane Miles (TLM)

The lane-miles of the road assigned to each FA varied significantly, from as few as 148 lane-miles to as many as 769. Naturally, the number of lane-miles will influence the costs. These were extracted from ~~IDT~~ ITD,s "HWY NEEDS" database by Haber et al (1). No new road sections were added to the states highway system after winter of 1986-87.

- Level of Service (LS)

~~IDT~~ ITD uses five winter maintenance standards. Level of service 1 (LS1) is the best maintenance standard and naturally requires more resources. On the other hand road sections under level of service 5 (LS5) are closed during the winter. Therefore, a foreman area that has more lane-miles under LS1 category will incur more winter maintenance cost. Level of service factor (LS) was defined by Haber et al (1) as ratio of weighted sum of lane-miles under each category to TLM. The weights selected were somewhat arbitrary and it is important to recognize that changing the weights will affect the fit of the model. The following formula was used to get LS:

$$LS = ((5*LS1) + (4*LS2) + (3*LS3) + (2*LS4) + (1*LS5)) / TLM$$

LS was computed for each year and then an average value was calculated corresponding to each FA. Although, there were no classification changes since 1986-87 winter, LS was updated to include 1987-88 and 1988-89 winters. Appendix A contains listing of level of service factor by year,for each FA.

- Winter Traffic Volume (WNTADT)

WNTADT is defined as the weighted average of daily winter traffic over road segments in a FA, with respect to lane-miles. It was computed by Haber et al (1) from data maintained in "HWY NEEDS" database.

- Road Curvature and Gradient (CURVES, CRCURVE and GRADE)

One of the factors that reflected the effects of curvature, CRCURVE, was simply the summation of the critical curves within each FA (one for each section), weighted by lane-miles of that section and divided by TLM for each FA. The other factor, CURVES, used to describe the curvature effects, was a weighted summation of the actual number of curves. Weights were assigned according to the degree of curve. The factor that described grade effects was the summation of the critical grade of each section, weighted by the length of each section and divided by TLM for the FA. These curvature and grade factors were defined by Haber et al (1) and were extracted using "HWY NEEDS" database.

- Passing and Stopping Sight Distances (PASSITP and STOPD)

"HWY NEEDS" database contains passing sight distance and critical stopping sight distance for each road section. They can be considered as the measure of the vertical and horizontal curvature. The summary factors, PASSITP and STOPD were computed by Haber et al (1).

- Terrain Type

Two factors were derived by Haber et al (1) to represent terrain urbanization and terrain topography. URBANP is simply the percentage of lane-miles within a FA which were classified as urban. Nonurban road sections were classified as rolling, flat or mountainous. TERRF was a weighted average of these nonurban classifications.

- Elevation

The elevation factor for each FA is the average elevation of the highway within that area. These were calculated by Haber et al (1), graphically, using a topographical map.

- Snow and Wind Factors

These variables were computed by Haber et al (1) based on a subjective input. A map showing wind drifting and snow accumulation effects on the road clearing operations was obtained from each FA. The degree of the effect was classified as severe, moderate, or light. Snow factor (SF) and wind factor (WF) were simply the weighted averages. Severe wind percentage (SWP) was the percentage of total lane miles which were classified under the "severe" category.

As suggested by ITD ~~IDT~~ personnel, for this project, wind drifting effects were classified under two categories significant and insignificant. The moderate and light wind categories were considered to be insignificant. The weights chosen for these two categories were somewhat arbitrary. WF was calculated as shown in following example:

FA 260	Wind Categories		
	Significant	Insignificant	Total LM
(weights)	(3)	(1)	
lane-miles	87	144 ~~114~~	231

$$WF = (3*87 + 1*\overset{144}{\cancel{114}}) / 231 = 1.75$$

The new wind factors so obtained are presented in Table 5-1. (Note : Tables, Charts and Figures are located at the end of this chapter.)

- Climate Factor and Temperature (CF and TEMP)

These factors account for climate and temperature differences between the FA,s. They were derived from the maps showing climatic differences over the state and minimum January temperature by Haber et al (1).

- Storm Intensity Factor or Average Storm Hours (ASH)

Storm intensity varies from FA to FA. The average number of storm hours expended, ASH, could be a reasonable factor to express storm intensity, as weather data is not available. This factor can also be a representation of factors that make road clearing operation difficult in a FA. ASH was previously defined by Haber et al (1) as the average number of manhours expended per day for a "peak storm". The peak storm was defined as "Those days whose total road clearing manhours exceed the mean plus one and one-half standard deviations". This cutoff level was chosen arbitrarily and can affect the values of this factor. Therefore, a sensitivity analysis was carried out to see the effect of cutoff level on ASH values.

Sensitivity Analysis of ASH :

ASH can be extracted from two similar data sets. One is the cost data set and the other is the maintenance data set. Both data sets should give the same results for manhours worked for winter storm activity. Haber et al (1) used the maintenance data set to get ASH values but here the cost data set was used to keep a uniformity of source. A complete comparison was run between both the data sets. This comparison showed a substantial agreement between the two data sets except for a small number of observations. These differences are attributed to reporting error.

Several other changes in the data set were made in this study. First, data from winters 1988 and 1989 were included, and secondly, storm manhours worked by special crews whose work areas may cross several standard foreman areas were also included in the updated data set. These special crew manhours especially affected the ASH value for Districts 3 and 6. Comparisons of updated ASH values with old ASH values are presented ~~in the form of chart~~ in Charts B-1 to B-6 of Appendix B.

The definition of peak storm, "Those days whose total road clearing manhours exceed some specified cutoff value" were exactly the same for both analyses. However, this study used a variable parameter K for the cutoff factor whereas previous research used K=1.5 as stated above.

The actual cutoff level is then determined by m+Ks; where m represents the average ASH over the winter season, s is the standard deviation and K is the cutoff factor.

Five cutoff factors were selected K = 1.65, K = 1.50, K = 1.28, K = 1.04, and K = 0.84. IF the ASH is distributed normally, these various K's can determine the percentage of total storm days used to calculate ASH. For instance, if K = 1.5, then only 6.7% of the days during the winter season were designated as " Peak Storm Days". When ASH values thus obtained were plotted against cutoff factor K for each FA, a linear trend was observed. For an example a graph for FA 240 is given in Figure 5-1. The linear trend indicates that there is not an abrupt change in ASH with different cutoff levels. The ASH values for various K values are summarized in Appendix B.

After discussion with ITD personnel the cutoff factor was selected to be 1.5.

TRANSIENT FACTORS

- Storm Frequency (N_ST)

The number of storms that occur in a FA varies from year to year. Storm frequency may therefore explain transient variations in cost. Storm frequency can be computed using the same definition of "peak storm". Storm frequency is the number of days in a winter season whose total road clearing manhours exceed some specified cutoff value. As a result of the sensitivity analysis the cutoff value was again selected as the mean plus one and one-half times the standard deviation. The cost data set was used to extract storm frequency values. These values for each district are listed by year in Table 5-2.

- Statewide Inflation Index (SII)

Cost is a function of the unit value of a commodity. The inflation index reflects the changes in the value of the commodity with time. So, the inflation index may be a candidate factor that could explain transient variations in cost. The winter maintenance costs are the sum of material, equipment and labor costs. The amount of material and equipment used is in some proportion to the labor expended. Therefore, labor or the manhours expended can be used as a base to compute the inflation index. Total annual cost per manhour expended can be a reasonable expression for inflation index.

A statewide inflation index was calculated for every year using the winter maintenance cost data set. Material, equipment and labor costs incurred every year over the entire state were summed and then divided by the number of manhours expended on winter maintenance over the state during that year. When statewide inflation indices were plotted against time, a linear trend was observed (refer to Figure 5-2). A regression equation was obtained with an R^2 of 0.87 . The value of the inflation index for the year 1982-83 was abnormally high, and it was treated as a outlier for regression. The inflation indices were corrected to fit this linear trend using the following equation :

$$SII = (1.22 * (year - 8384) /101) + 33.27$$

For example, the statewide inflation index for 1986-87 is

$$SII = (1.22 * (8687 - 8384) /101) + 33.27 = 36.93$$

Statewide inflation indices are listed in Table 5-3.

- Total Storm Hours (TSH, d_TSH)

The total storm hours expended every year change because of changes in storm frequency and intensity. The total storm hours expended during a winter season on "peak storms" were obtained from the cost data set. As a result of sensitivity analysis, the cutoff value to identify a "peak storm" was again selected as the mean plus one and one half times the standard deviation. Another factor, d.-TSH, was proposed in an attempt to explain transient variations in cost. d_TSH is the yearly deviations from the average of TSH taken over time. Values of TSH and d.-TSH are listed in Table 5-2.

A detailed FA-wise listing of transient factors is attached in Appendix C.

DEPENDENT VARIABLE

- Total Average Cost (TAC)

The dependent variable of the cost model was the average yearly cost incurred while performing any winter maintenance activity. These activities included: application of abrasives, clearing, other snow and ice control methods and brooming. They are coded under activity number M331, M332, M334 and 118. For a detailed description of each, reader is directed to ITD Maintenance Operation Procedures (7).

TAC was computed from the cost data set and included material, equipment and labor costs. Sometimes the costs were coded under special foreman areas which may cross several standard foreman areas. These costs were prorated to the standard foreman areas, based on the beginning and end mile posts of the road segment. It was assumed here that the cost is uniformly distributed over the length of the road segment. Material, equipment, labor and total cost are listed by year for each FA in Appendix D. TAC values are listed in Table 5-4.

Table 5-1

Wind Factor Data

FA	WIND SIGNIFICANT	WIND INSIGNIFICANT	TLM	WF
120	0	148	148	1.00
130	0	309	309	1.00
140	21	143	164	1.26
150	50	207	257	1.39
160	48	190	238	1.40
170	0	321	321	1.00
220	201	44	245	2.64
240	239	0	239	3.00
250	187	42	229	2.63
260	87	144	231	1.75
270	149	70	219	2.36
290	173	85	258	2.34
320	0	292	292	1.00
330	0	296	296	1.00
340	70	260	330	1.42
350	474	154	628	2.51
370	13	466	479	1.05
380	24	184	208	1.23
390	0	167	167	1.00
430	690	79	769	2.79
450	354	195	549	2.29
460	407	81	488	2.67
480	152	137	289	2.05
490	250	52	302	2.66
530	234	82	317	2.48
540	218	88	306	2.42
550	74	121	196	1.76
560	187	135	322	2.16
570	120	144	264	1.91
580	241	44	285	2.69
590	115	79	194	2.19
640	210	0	210	3.00
650	371	0	371	3.00
660	270	227	497	2.09
670	448	0	448	3.00
680	460	0	460	3.00
690	492	0	492	3.00

Figure 5-1

Linear Trend of ASH with respect to Cutoff Factor (K)

FA 240

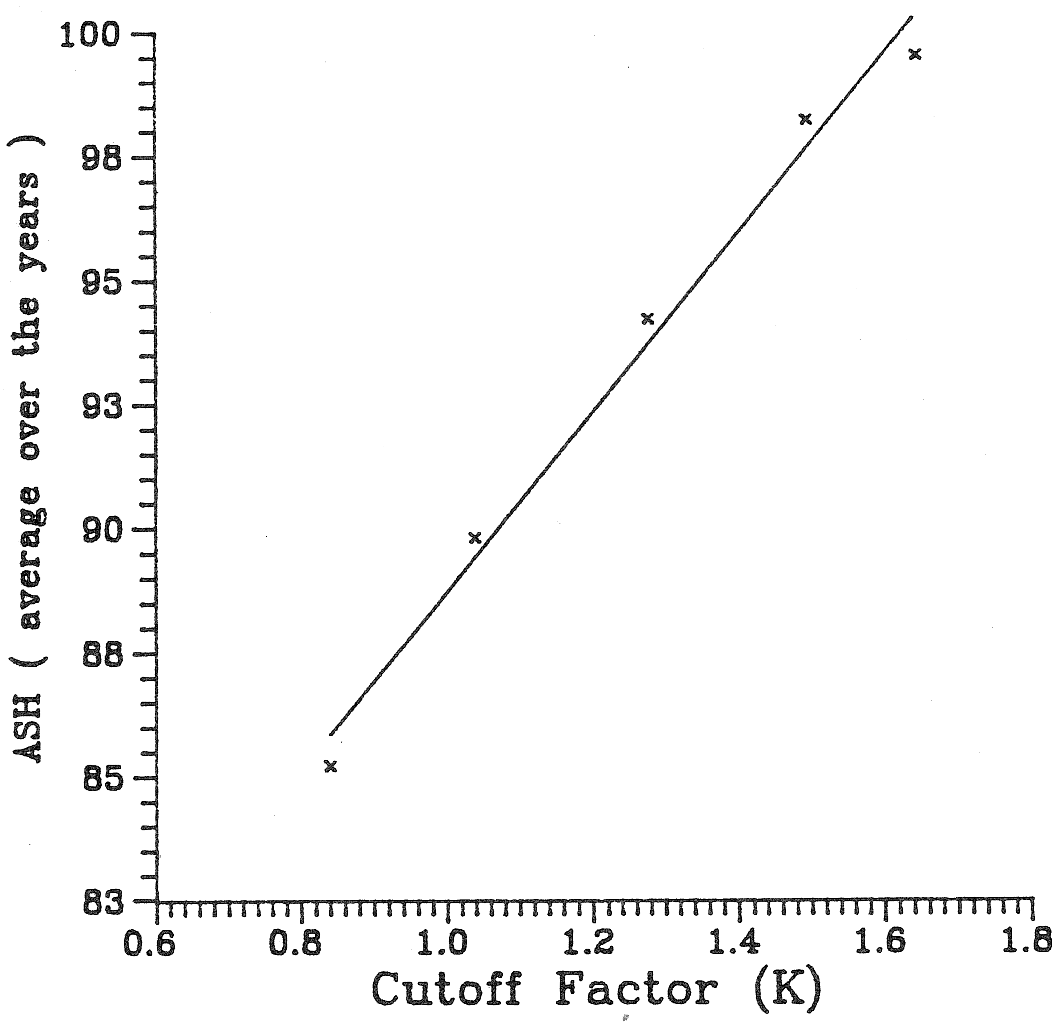


Table 5-2

Summary of Transient Variables

DIST	YEAR	TSH	D_TSH	N_ST	PREDICTED COST	ACTUAL COST
1	8283	6802.7	-1583	64	1591536	1284645
1	8384	6435.5	-1951	65	1591536	1359919
1	8485	9812.0	1426.0	77	1591536	1776369
1	8586	9173.0	787.0	79	1591536	1785130
1	8687	5533.0	-2853	64	1591536	1555633
1	8788	7853.9	-532.1	80	1591536	1664194
1	8889	13092	4706.0	92	1591536	2425516
2	8283	4524.0	-1846	61	1196669	736349
2	8384	6580.7	211.1	76	1196669	896913
2	8485	8314.0	1944.4	82	1196669	1128899
2	8586	6537.0	167.4	80	1196669	1057585
2	8687	3923.0	-2447	54	1196669	937995
2	8788	5508.0	-861.6	64	1196669	1065887
2	8889	9200.7	2831.1	85	1196669	1509281
3	8283	6631.2	-74.8	82	1117433	881064
3	8384	8947.8	2241.7	90	1117433	1244329
3	8485	6794.5	88.5	79	1117433	1106645
3	8586	6928.1	222.1	70	1117433	1291420
3	8687	3871.5	-2835	61	1117433	795732
3	8788	5332.2	-1374	66	1117433	962986
3	8889	8437.1	1731.0	84	1117433	1572604
4	8283	4905.4	36.5	41	779954	658833
4	8384	7164.0	2295.1	54	779954	879360
4	8485	4665.0	-203.9	39	779954	712458
4	8586	5481.0	612.1	43	779954	871008
4	8687	2996.7	-1872	35	779954	442024
4	8788	3293.0	-1576	31	779954	598743
4	8889	5577.0	708.1	46	779954	896490
5	8283	5617.9	-148.6	65	1196678	1206456
5	8384	7813.8	2047.3	77	1196678	1546154
5	8485	5954.0	187.5	62	1196678	1291554
5	8586	6712.1	945.6	66	1196678	1316081
5	8687	3517.0	-2250	53	1196678	637459
5	8788	4866.9	-899.6	54	1196678	1068769
5	8889	5884.0	117.5	61	1196678	1447643
6	8283	8354.8	1619.1	89	892143	1052822
6	8384	7414.9	679.2	78	892143	1008583
6	8485	7684.1	948.4	73	892143	1057276
6	8586	6582.3	-153.4	66	892143	1001634
6	8687	4192.0	-2544	62	892143	553930
6	8788	4840.0	-1896	62	892143	800056
6	8889	8081.8	1346.1	68	892143	1334466

Table 5-3

Statewide Inflation Index by Year

YEAR	WINTER INDEX	TOTAL WINTER MAINTENANCE COST	TOTAL WINTER MAINTENANCE MAN-HOURS	STATEWIDE INFLATION INDEX	CORRECTED STATEWIDE INFLATION INDEX
8283	1	5820169	160190	36.3329	-
8384	2	6935258	210243	32.9869	33.27
8485	3	7073201	209286	33.7968	34.49
8586	4	7322858	196531	37.2606	35.71
8687	5	4922773	132655	37.1096	36.93
8788	6	6160635	165023	37.3320	38.15
8889	7	9186000	233005	39.4240	39.36

Figure 5-2

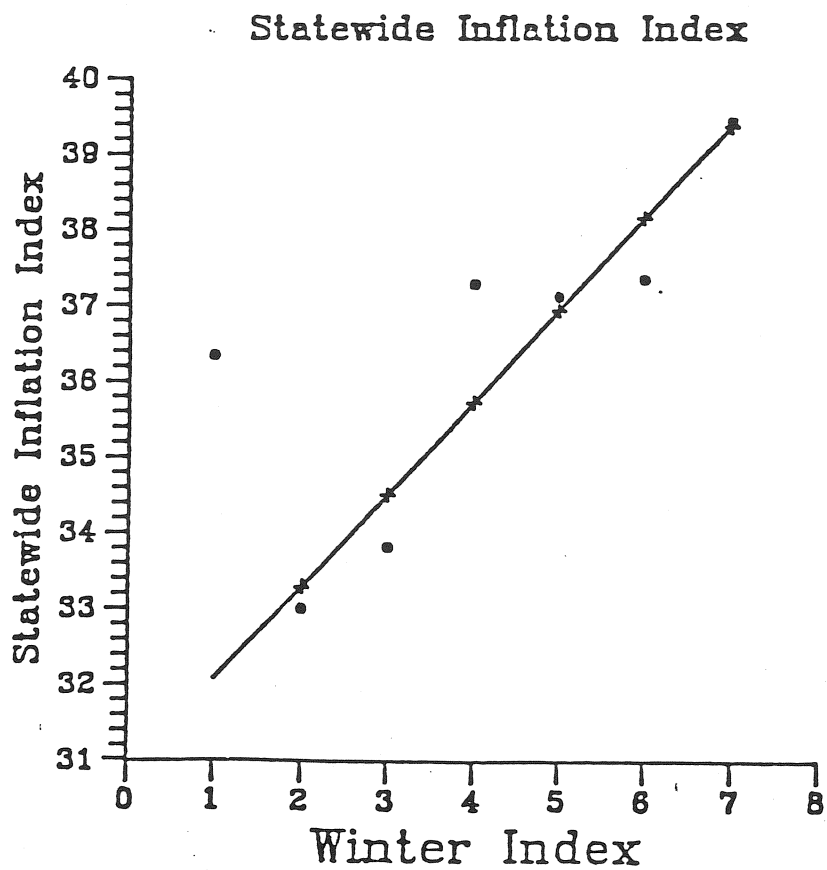


Table 5-4

Labor, Equipment, Material and Total Cost
(Average over the years)

FA	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
120	48251	42342	39943	130537
130	100612	114454	75468	290533
140	101978	121589	76104	299671
150	97428	132837	109609	339874
160	96039	80673	83627	260339
170	133599	118644	119861	372104
220	70239	74882	38755	183876
240	73932	59763	45976	179671
250	58307	49204	21926	129437
260	113379	93477	55155	262012
270	62733	51217	34277	148227
290	74055	54471	15808	144334
320	83848	80568	31239	195656
330	47505	40664	19731	107901
340	55431	50720	41689	147840
350	68832	65202	33273	167307
370	55901	55048	38990	149938
380	73862	82754	33849	190465
390	71150	80803	11053	163005
430	80091	76929	59441	216461
450	68560	58502	16406	143468
460	31449	30149	30535	92134
480	87884	82391	9846	180121
490	34744	31586	24190	90519
530	72751	73031	67708	213490
540	45294	47981	54825	148100
550	45340	44924	56760	147024
560	32831	32631	21022	86484
570	38640	37273	29063	104977
580	83136	118923	97110	299169
590	80269	77584	59205	217059
640	110214	121980	5342	237536
650	83665	75571	8178	167414
660	78641	78221	22449	179310
670	30721	26089	1856	58666
680	58171	49064	4841	112075
690	103902	89885	23893	217680

Chapter 6: Developing the Cost Model

As noted earlier, independent variables were categorized into two groups - steady-state variables and transient variables. As it was not possible to mix them together to form one model, a two stage approach was used. In the first stage, a model was constructed with steady-state independent variables to explain the total average cost (TAC). Multiple regression analysis was used to formulate the relationship between TAC as a response variable and several regressor variables such as TEMP, LS, SF and WF.

SAS procedures were used to fit the linear model. SAS uses the method of least squares to compute coefficients of independent variables. The difference between observed and predicted values of the dependent variable is called a residual. The method of least squares minimizes the sum of squares of the residuals (SSE). The procedure involves solution of simultaneous equations, and the number of equations to be solved depends on the number of independent variables. If the model has n independent variables, n+1 simultaneous equations are required to be solved to find n coefficients and one intercept. SAS uses time efficient numerical procedures to invert and multiply the matrices involved.

One of the most difficult problems in regression analysis is the selection of independent variables to be employed in the model. The number of these independent variables should be small enough so that model maintenance costs are manageable and analysis is facilitated. On the other hand, it should be large enough so that adequate description, control and prediction is possible. None of the subsets of independent variables is usually "best" for all purposes. Even for a given purpose it is often found that several subsets are about equally "good" according to a given criterion. So, the choice of the subset variables should not be based solely on the statistical selection procedures. The entire selection process is pragmatic and often involves subjective judgment.

- The stepwise regression procedure is probably the most widely used method of the automatic search methods. It was developed to economize computational effort, while arriving at a reasonably "good" subset of independent variables. This search develops a sequence of regression models, at each step adding or deleting an independent variable. STEPWISE, the SAS procedure has three options for the variable selection - forward selection, backward elimination and the stepwise search. The criterion for adding or deleting an independent variable can be stated in terms of significance levels. F statistics, which is the ratio of drop in sum of squares to mean square error, is used to test the significance of the parameter at an entry and exit state. The stepwise search was used with 5% level of significance to determine which independent variables and interactions were significant.

- When the independent variables are correlated amongst themselves, intercorrelation or multicollinearity is said to exist. Selection of independent variables is affected by multicollinearity.

Correlated independent variables provide redundant information to the model and the predictive power of the model becomes questionable. In this study, TEMP (mean January temperature) was highly correlated to ELEV (average elevation). They showed a correlation of -0.91, and therefore they should not be used in the same model. Other pairs of correlated variables included CF (climate factor) and SF (snow factor), TERRF (terrain factor) and CRCURVE (critical curve classification factor), and also PASSITP (passing sight distance factor) and STOPD (stopping sight distance factor).

After the steady-state cost model was formulated, it was used to predict the response variable from the known set of independent variables. These predicted values were summed district wise to obtain the average predicted cost for each district. Actual yearly costs varied from winter to winter. This deviation of the annual district costs from the average predicted district cost was explained by six transient models - one for each district. Each model was regressed over seven data points for seven winter seasons. As there were only three independent candidate transient variables, all possible regressions were performed and the best fit models were selected. Computer outputs of the best fit models - steady state and transient - are attached in Appendix E.

Annual winter maintenance costs were then predicted for every district, by first applying the steady-state cost model and then the transient cost model for that district. A user friendly computer program was written in Quick BASIC. This program can be used as a tool to predict winter maintenance costs - average annual cost for any FA and seasonal cost for any district. The program uses historic values of independent variables as a default input. These default values can be changed by the user during execution. The program listing is attached in Appendix F.

Chapter 7: Analysis of Benefits

The objective of winter maintenance activities is to provide a better quality, safe surface to the road users. ITD expends a significant amount of resources on snow and ice control activities. As a consequence, benefits are gained by the users and the non-users of the highway. Changing the level of service has immediate effect on delay, traffic safety, traffic congestion and also on the public image of the Transportation Department.

User benefits of the winter maintenance can be classified under the following categories:

- Accident reduction or increased travel safety
- Decreased travel delay
- Increased travel comfort
- Reduction in operating cost of the vehicle
- Reduction in business losses (e.g produce spoilage)
- Vehicle corrosion due to use of deicing salt (a negative benefit)

Non-user benefits are often negligible compared to those experienced by road users (2). In this study an attempt is made to quantify the user benefits due to accident reduction, decreased delay and discomfort and to correlate them with change in level of service.

A database containing information about the accidents that occurred on Idaho roads was obtained from ITD. These records dating back to 1983-84, showed the location, vehicle and person information. Location information contains several data fields such as date, segment code, milepost, number of injuries and fatalities, road surface condition etc. ITD has revised winter maintenance standards for fifteen road sections since the winter of 1986-87. Table 7-1 shows these road sections with previous and revised level of service. The accidents database was summarized, and accidents that occurred on the road sections listed in Table 7-1 with 'ice, or 'snow, as the road surface condition were separated as winter accidents. In reality accidents occur as a combined effect of three contributing factors - human, vehicle and environmental. Environmental factors commonly interact with some other factor - human or vehicle - during an accident. According to the study by Wright and Baker (7), only four percent of the accidents occur due to environmental factors alone. As it is virtually impossible to separate these contributing factors, it is assumed here that for the accidents listed with 'ice, or 'snow, as the road surface condition, environment is the major contributing factor.

Average yearly injuries and fatalities per mile of road were computed for winter accidents for two time periods before the revision and after the revision - for all road sections that underwent a change in level of service in 1986-87. These average annual rates are listed in Table 7-2.

Since fatalities occurred on only three of these fifteen road sections, no correlation, quantitative or qualitative, in fatality rate and level of service was attempted due to insufficient data.

However, an attempt was made to form a regression model that could explain change in injury rate with change in level of service. For the road sections where level of service was decreased during revision, injury rates for two time periods were swapped and then it was treated as an increase in level of service during revision. Various ways to normalize the response variable (such as per mile rate, percent reduction) were attempted. None of these models showed an R^2 more than 0.08 . Though no quantitative correlation could be developed, the data indicated that injury rate (average annual injuries per mile) might be reduced with an increase in level of service. To test this statistically, the Wilcoxon signed-rank sum test was performed. This is a nonparametric test for paired data and does not require any statistical concerning the statistical distribution of the ? except normality of the two populations the populations should be identical under the null hypothesis. Null and alternate hypotheses and the test calculations are shown in Table 7-3. The test resulted in rejection of the null hypothesis with 5% probability of type I error. So, with 95% confidence it can be concluded that injury rate drops with increase in level of service. The reason that the data supports a qualitative model but fails to support any quantitative model could be that the injury rate decreases, though not proportionally, with increase in level of service.

Travel speed depends on the condition of the road surface. Better speeds can be achieved on well maintained roads, saving travel time. Moreover, the road users can travel comfortably on well maintained roads. Increasing the level of service, will benefit the users by saving their time and increasing the travel comfort and convenience. The magnitude of time saved by a vehicle is given by :

$$Time\ saved = Trip\ Length * \left[\frac{1}{V_{old}} - \frac{1}{V_{new}}\right]$$

where,

V_{old} = Speed on previous level of service

V_{new} = Speed on upgraded level of service

The speeds V_{old} and V_{new} will vary from vehicle to vehicle. The delay will also vary and the way it varies depends on the probability distributions of V_{old} and V_{new}. Trip length will also be a variant but if data are not available it can be assumed constant. Studies done previously by other researchers (3,4,11) show that dry road speeds are distributed normally and it was assumed the same for snow speeds. The probability distribution for time saved, consisting of the difference between the reciprocals of two normally distributed variables, is extremely complex. If it were simpler, however, it could be integrated to obtain benefits due to comfort and convenience and due to savings in lost wages. Stochastic simulation is probably the best alternative in such a case. Knowing the mean and standard deviation for V_{old} and V_{new}, random normal variates can be generated to represent the two speeds. If average trip length is known, time saved or lost on ? can be computed. The distributions parameters for V_{old} and V_{new}, used in this study are obtained from a study done by Utah Department of Transportation (3,4) and are listed below in Table 7-4 .

Table 7-1

Distribution Characteristics for Speed

LEVEL OF SERVICE	CATEGORY	DRY ROAD SPEED (Mean)	DRY ROAD STANDARD DEVIATION	REDUCTION FACTOR	SNOW SPEED	SNOW SPEED STANDARD DEVIATION
1	Inter-state	50.0	4.2	0.78	39.0	5.1
1	Other	41.0	5.8	0.79	32.4	4.1
2	Inter-state	50.0	4.2	0.70	35.0	5.1
2	Other	41.0	5.8	0.75	30.8	4.7
3	Inter-state	50.0	4.2	0.58	29.0	4.2
3	Other	41.0	5.8	0.58	23.8	4.0

Benefits of time savings or cost of delay are subjective. Time has different value for different persons and to the same person on different occasions. Moreover, small time savings are of less unit value than the time savings of a considerable amount. So, a million persons saving one minute each, does not have the same value as 100,000 persons saving 10 minutes each. On the other hand, it is relatively simple to put a dollar value on the delays experienced during work-oriented trips. Wages lost due to delay can be a good measure of cost and when this delay is avoided it is a benefit. Several researchers have formulated lost wages as a function of delay through a process of questioning and interviewing the highway users. These functions are linear and no wage is lost if the delay is below some threshold value (refer to Figure 7-1). This threshold value changes from industry to industry and is recognized in most union contracts.

Similar functions that translate the delay to discomfort and inconvenience cost have also been developed by other researchers. These functions are different for different income groups. But if they are not available, a function for an average income group may be used. Generally, these functions are non-linear but may be linearized into two to three segments (refer to Figure 7-2). The concept illustrated by these functions is intuitively appealing - a delay of five minutes may not cause any inconvenience and the additional cost of~~f~~ being 30 minutes late rather than being 25 minutes late is not as significant as the difference between being 10 minutes late and being 15 minutes late.

In this research the functions formulated by the Utah Department of Transportation (3,4) in 1977 are used with a correction to account for inflation. This correction factor is a function of time and is defined as ratio of average hourly wage during the year under consideration to the average hourly wage during 1977 ($5.10 /hr). Average hourly wages for all the years from 1977 to 1987 were calculated by dividing "Total amount of wages given" by "Total number of employees", for every year. The required data was obtained from "County Business Patterns - Idaho" - a federal government publication (8). With average hourly wage as a response variable and time as a independent variable, a linear fit was obtained with $R^2 = 0.94$. Values of actual and predicted average hourly wages and the correction factors are listed in Table 7-5.

As a result, a user friendly simulation program was written in QuickBASIC. Knowing the average daily winter traffic, percentage of traffic that contributes to work oriented trips, current and proposed levels of service and the average trip length; benefits due to comfort and convenience and due to savings in wages can be obtained. The distributions and the functions used in the program can be changed easily if required at a later stage. The program listing is attached in Appendix G.

Table 7-2

Revisions to Level of Service
(Winter 1986-87)

Road Segment Code	From	To	Beginning Mile Post	Ending Mile Post	Previous Level of Service	New Level of Service	Road Section Refer.
001540	Plummer	Coeur d'Alene	395.730	429.606	2	1	D11
001540	Bonn Fery	Eastport	508.406	538.562	3	2	D12
001910	Spalding	Orofino	10.130	40.663	2	1	D21
002050	OR Line	Homedale	0.000	4.827	4	3	D31
002050	Wilder	Caldwell	9.070	19.915	3	2	D32
002070	Parma	Caldwell	9.640	22.129	3	2	D33
002190	Hammett	Jct. I-84	94.664	98.640	3	4	D34
001540	Palis.Jct.	Payette	61.078	66.953	2	1	D35
002140	Lowman	Stanley	69.639	130.869	5	4	D36
002270	W Jerome	Jct. US-93	0.626	5.342	2	1	D41
002360	Preston	Jct. US-30	8.560	50.476	2	3	D51
002360	Soda Spr.	Conda Jct.	59.795	63.549	2	3	D52
002320	Roy	Rockland	37.483	55.440	3	4	D53
002460	Jct.20/26	Jct SE-22/33	0.000	24.680	3	4	D61
002520	Jct. US-20	Montana Line	0.000	9.145	3	4	D62

Note: The second digit of road segment reference indicates the District. For example-"D35" is in District 3.

TABLE 7-3

Injury and Fatality Rates

ROAD SECTION REFERENCE	LENGTH OF ROAD	LEVEL OF SERVICE BEFORE 1986-87	LEVEL OF SERVICE AFTER 1986-87	FATALITY RATE (BEFORE)	FATALITY RATE (AFTER)	INJURY RATE (BEFORE)	INJURY RATE (AFTER)
D11	33.876	2	1	0.00	0.01	1.09	0.76
D12	30.156	3	2	0.07	0.00	0.25	0.23
D21	30.533	2	1	0.02	0.02	0.95	0.34
D31	4.827	4	3	0.00	0.00	0.14	0.00
D32	10.845	3	2	0.00	0.00	1.29	0.92
D33	12.489	3	2	0.00	0.00	0.04	0.20
D35	5.875	2	1	0.00	0.00	0.68	0.23
D36	61.230	5	4	0.00	0.00	0.00	0.07
D41	4.716	2	1	0.00	0.00	0.78	0.00
D51	41.916	2	3	0.00	0.00	0.12	0.00
D52	3.754	2	3	0.00	0.00	0.00	0.00
D53	17.957	3	4	0.00	0.00	0.00	0.03
D61	24.680	3	4	0.00	0.00	0.08	0.04
D62	9.145	3	4	0.00	0.00	0.00	0.00

Notes :

1. BEFORE : This is the average rate before 1986-87 or for winters 1983-84, 1984-85 and 1985-86.

2. AFTER : This is the average rate after 1986-87 or for winters 1986-87, 1987-88 and 1988-89.

3. Average rates are in number per year per Mile.

Table 7-4

Wilcoxon Signed-Rank Sum Test

HO: Distribution of difference is symmetric about zero
or
Injury rate is not affected by change in Level of Service

Ha: The difference tends to be larger than zero
or
Injury rate decreases with increase in Level of Service

Injury Rate (Before)	Injury Rate (After)	Diff-erence	Rank	Signed Ranks	Positive Ranks	Negative Ranks
1.09	0.76	0.33	7	7	7	
0.25	0.23	0.02	1	1	1	
0.95	0.34	0.61	10	10	10	
0.14	0.00	0.14	5	5	5	
1.29	0.92	0.37	8	8	8	
0.04	0.20	-0.16	6	-6		-6
0.68	0.23	0.45	9	9	9	
0.78	0.00	0.78	11	11	11	
0.00	0.12	-0.12	4	-4		-4
0.03	0.00	0.03	2	2	2	
0.04	0.08	-0.04	3	-3		-3
	Sum of ranks =		53	-13		

Test Statistics = ABS(SUM(negative ranks))

$= | -13 | = 13$

T* (0.05) = 13

as, T = T*

reject H_o with probability of type I error = 0.05

or

accept H_a with 95 % confidence.

TABLE 7-5

Inflation Correction Factor for "$=f(time)" Functions

Year	Total Wages (in thousands) of dollars)	Total number of Employees	Calculated Average hourly Wage $/hr.	Predicted Average Hourly Wage $/hr.	Inflation Correction Factor
1977	2391023	219275	5.24	5.10	1.00
1978	2511366	239957	5.03	5.42	1.06
1979	2870095	249511	5.53	5.74	1.13
1980	3065127	245752	6.00	6.06	1.19
1981	3299265	241738	6.56	6.38	1.25
1982	3337007	232263	6.91	6.70	1.31
1983	3572128	230982	7.44	7.02	1.38
1984	3874388	246619	7.55	7.34	1.44
1985	1098497	252957	7.79	7.66	1.50
1986	4085799	254550	7.72	7.98	1.56
1987	4202751	253334	7.98	8.30	1.63
1988	--	-	-	8.62	1.69
1989	-	-	-	8.94	1.75

Regression Output:

Dependent variable : Average Hourly Wage
Independent variable : Year

Constant	-627.019
Std Err of Y Est	0.279603
R Squared	0.941117
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	0.3197378
Std Err of Coef.	0.03

Average Hourly Wage = (0.3197378 * Year) - 627.02

Figure 7-1

Lost Wages as a Function of Tardiness

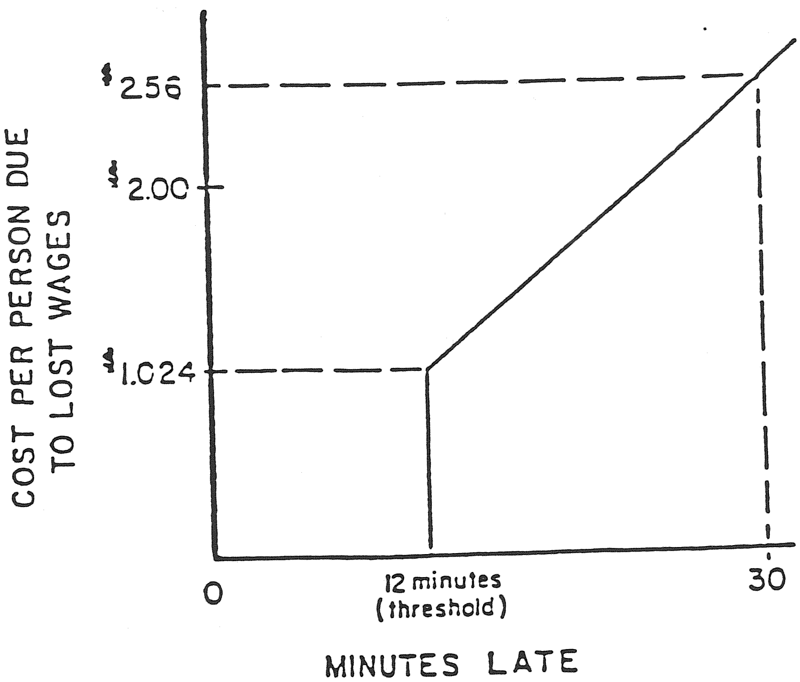
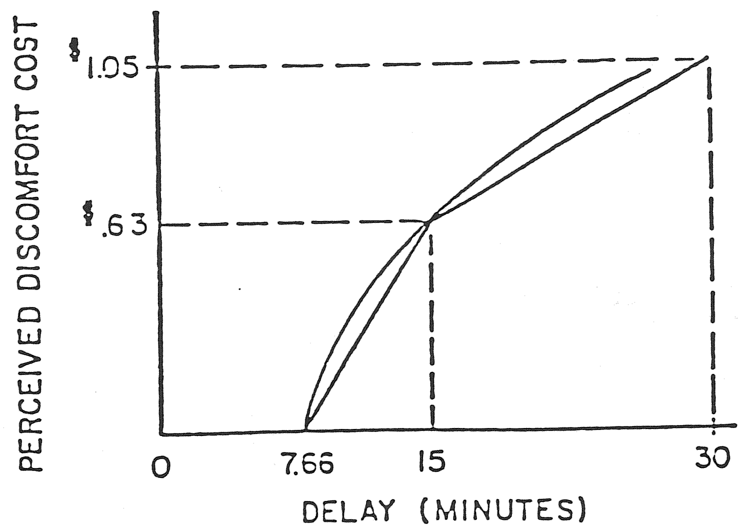


Figure 7-2

Cost of Discomfort
as a function of Delay



Chapter 8: Results

Using the variable selection procedures, the number of candidate models that could explain total average cost as a function of steady-state independent variables, was reduced to five. Several models with high coefficients of determination were rejected because of the multicollinearity problem discussed in Chapter 6. Based on the coefficient of determination, personal judgment and discussion with ITD personnel, the best fit model was selected.
The best fit model has a coefficient of determination of 0.74 which indicates that 74% of the variability in total average cost is explained by the model. Independent variables in the model are either in the original form or cross-products to represent the interaction and are statistically significant at 0.05 significance level. No particular functional form for independent variables was suggested by analysis of residuals. The coefficients, independent variables and their definitions are listed in Table 8-1.

Six transient models, one for each district, were then formulated to explain difference in annual district cost and predicted average district cost. The coefficient of determination for these models varies from 0.89 0.86 to 0.98. The coefficients for each district model, the independent variables included and their meanings are listed in Table 8-2.

Average maintenance costs for any FA can be predicted using the steady-state cost model. Average maintenance cost, occurred and predicted, are listed in Table E-2 of Appendix E. Maintenance costs for a district can be predicted by first applying the steady-state model, then summing the average costs for the FA,s in that district and then applying the transient cost model. To guide the user through this process, a user friendly program has been written. A floppy disk containing an executable file "COST.EXE" and the program source code "COST.BAS" is included in the Appendix H. The disk also contains two data files "STEADY.DAT" and "TRANS.DAT", which are required to run "COST.EXE". The program uses the default values from these data files. These defaults can be easily changed during the execution of the program. Actual and predicted winter costs for each district are compared in Charts 8-1 through 8-6. They are also listed in Tables E-4 to E-9 of Appendix E.

A simulation program that simulates the differential delay with change in level of service and calculates the savings in lost wages and benefits due to comfort and convenience in dollars was written as a result of the benefit analysis. A floppy disk containing an executable file "SIMUL-B.EXE" and the program source code "SIMUL-B.BAS" is included in the Appendix H. For example, if the level of service for a 50 mile long non-Inter~~-~~state road section with average daily traffic of 10000, average trip length of 40 miles and percentage of work oriented traffic 60% is increased from 2 to 1; total benefits gained from comfort, convenience and savings in lost wages are $1068.40 per day. It may be noted here that the random number generator is seeded during each run and the output costs may not match exactly when re-simulated with the same input.

Differential benefit cost analysis to set winter maintenance levels is not advisable at this stage because insufficient data has not permitted this research to account for accident avoidance benefits. But, it can be concluded with a 5% level of significance that injuries do decrease with the increase in level of service.

Table 8-1

Best-Fit Steady-State Cost Model

Coefficient	Term	Term Definition
-104424.75000	Intercept	
359.16969	LSASH	Level of Service Factor Average Storm Hours
0.03117893	ELEVTLM	Elevation * Total Lane Miles
0.16115399	CURVETLH	Curves * Total Lane Miles
91273.35657	SF	Snow Factor
-18016.65832	WF	Wind Factor

Table 8-2

Best-Fit Transient Cost Models

(by District)

District	Intercept	DELST	SII	Coefficient of Determination
1	-1998415.36	103.54888	58806.60728	0.97
2	-2101996.72	80.10650	54688.59743	0.98
3	-1960038.66	142.68567	55019.92453	0.92
4	- 889279.39	123.52476	23300.08528	0.89
5	19623.79488	203.80901	-	0.86
6	-1467198.73	164.27308	43348.41394	0.97

Note : SII = Statewide Inflation Index
DELST = Deviation from the average manpower expended on storms.

Chart 8-1

Comparison of Actual and Predicted Winter Maintenance Costs

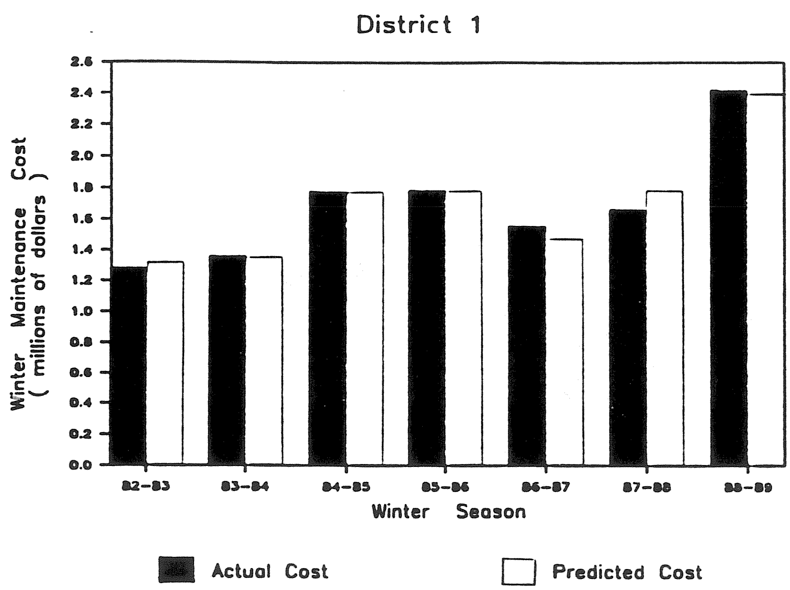


Chart 8-2

Comparison of Actual and Predicted Winter Maintenance Costs

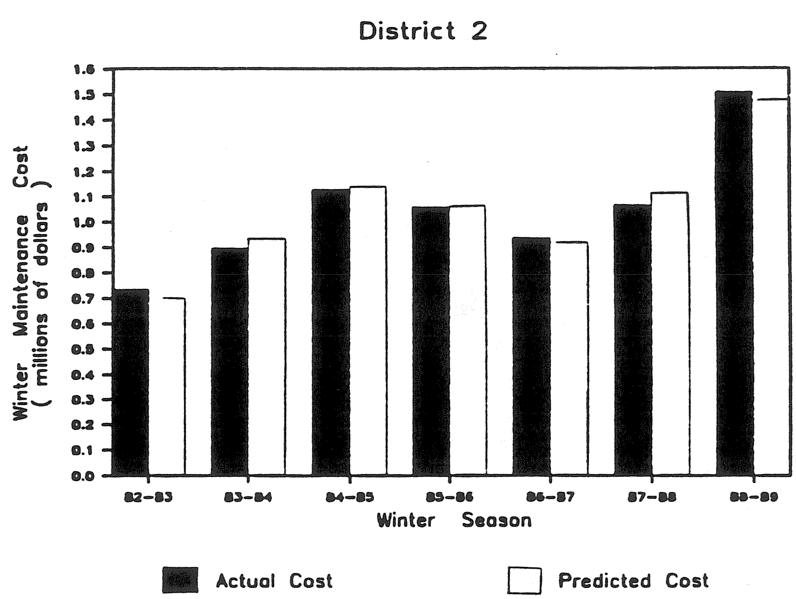


Chart 8-3

Comparison of Actual and Predicted
Winter Maintenance Costs

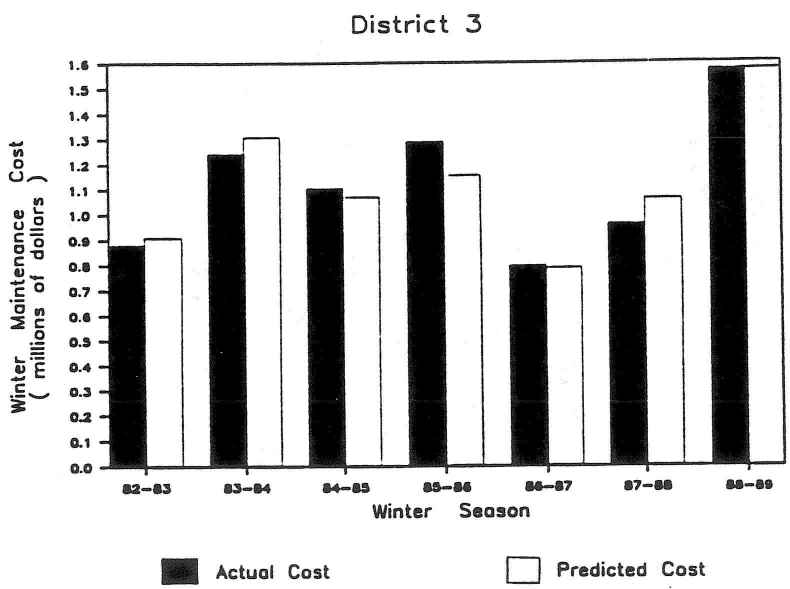


Chart 8-4

Comparison of Actual and Predicted
Winter Maintenance Costs

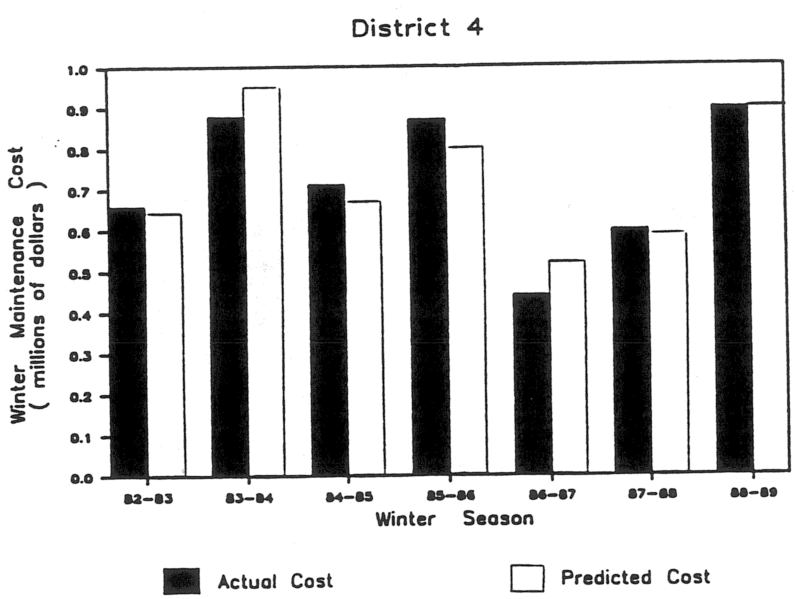


Chart 8-5

Comparison of Actual and Predicted Winter Maintenance Costs

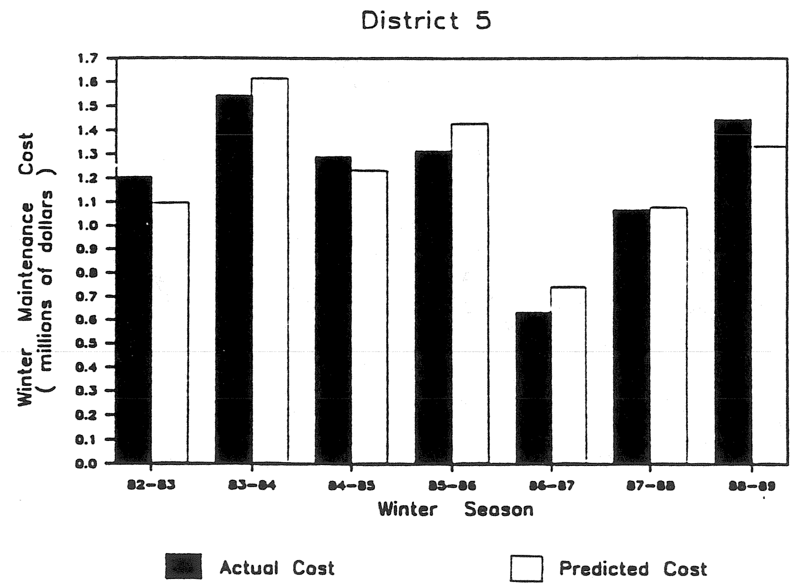
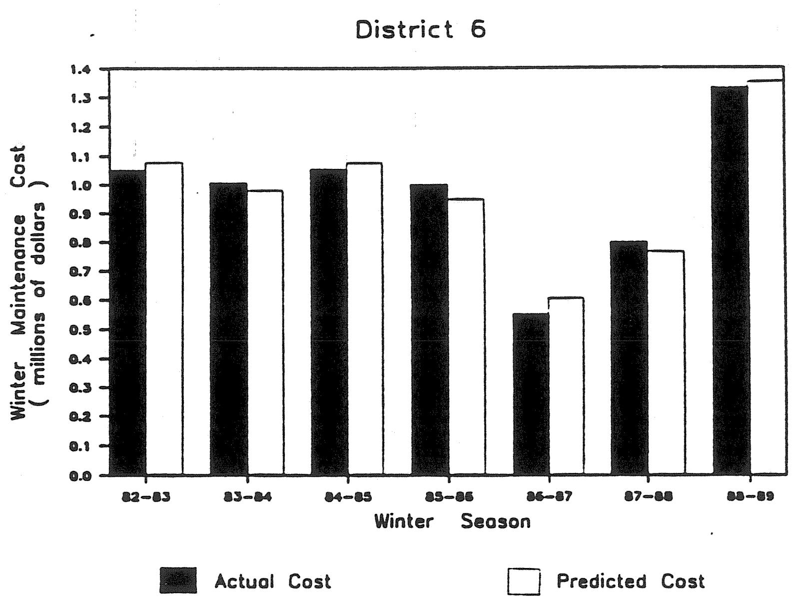


Chart 8-6

Comparison of Actual and Predicted Winter Maintenance Costs



Chapter 9: Conclusions and Recommendations

The cost models developed under this project can be of great help as a quantitative tool to predict costs, thus providing necessary information in formulating a management decision on winter maintenance levels. It must be recognized, however, that the model is based on significant qualitative and subjective assumptions. These assumptions must be carefully reviewed before using the model as a predictive tool. The benefit model developed in this phase of study is still incomplete and can only predict the differential benefits gained from increased comfort and convenience and from savings in decreased lost wages, with increase in level of service.

Although selection of independent variables, summarizing databases and formulating the models was done with highest scrutiny, it is not recommended to make any management decisions based solely on these models. Though the cost model shows fairly close predictions of the historical costs, it should be validated for one or more years before it is used as a decision making tool. The scope of the benefit model should be extended to account for differential benefits due to accident avoidance. For this, it is recommended that a phase of data collection and model building be planned and executed in the future. Once these benefits are accounted for and the cost models are further validated, differential benefit-cost analysis for change in level of service could be done. Some specific comments and recommendations that may be helpful in planning this phase are :

1. To correlate fatality rate with change in level of service, more data for fatalities is required. Data from other states might also be used with a proper matching of levels of service. Test road sections with current level of service of 2 or below may be selected and changes in fatality and injury rates with respect to upgrading of level of service could be studied. Along with the data collection, validity of empirical models, like the one currently used by ITD, may also be verified.

2. The functions that covert time savings to comfort and convenience benefits and savings in the lost wages because of delays, should be updated. Functions used in this research were obtained from a study completed in 1978. Though monetary values are corrected for inflation, the overall nature of these functions may need a revision. For example, in 1978 no wages were docked for a delay within 12 minutes. As of today, chances are that this threshold value may have changed significantly. Data collection through communication with the road users and then restructuring these functions is required. Similarly, means and standard deviations for the snow speeds used here are same as those in 1978. But in reality, there is a probability that they have changed with improved car technology.

3. Many variables used in the cost model are the weighted factors of subordinate variables. A sensitivity analysis of the model

results with respect to these weights may be conducted. The snow factor for example, was derived by weighing the severe snow lane-miles by 3, the moderate snow lane-miles by 2 and light snow lane-miles by 1. Similar weighing schemes were used for many other factors (e.g. WF, LS, CF, ELEV). These weights can perhaps be improved so as to reflect actual differences in costs for subordinate terms. Again using the snow factor as an example, if it costs 10 times more to maintain a lane mile with severe snow than a lane mile of light snow, the ratio of the weights used for severe and light snow should be 10.

4. ITD's cost database was the source for extracting the costs for winter maintenance. The database also includes the information about the beginning and ending mile posts of the road on which the work was done. Unfortunately much of this mile post data cannot be easily used because an activity could start on one road segment and end on some other road segment. If it would not have been the case, multiple regression analysis could have been based on 1770 road sections in the state as unique observations rather than 37 foreman areas. Such a dramatic increase in number of observations could result in a better model.

5. The study is based on the costs reported for winters 1982-83 to 1988-89. Level of service data prior to 1982 was not available. Since the model is based on historical data, it

should be updated after every 4 to 5 years as the new data becomes available. Updating the model every year would not be very cost effective. Such a continued updating of dependent and independent variables will be helpful in refining the model.

6. Use of the model should be limited to the range of observations on which the model was based. Extreme caution must be taken when predicting the response variable outside the range of observed data. For example, if a new foreman area is formed by combining the parts of several others, the reliability of the model to predict the costs for the new foreman area should be checked.

The work conducted during this study can be used as a foundation for the next phases. A great deal of data has been analyzed and are stored on tapes. Any adjustments to the model can be accomplished with minimal effort during the next stage. It is hoped here that the programs developed during this phase and those that will result from recommended studies, will result in a powerful benefit-cost analysis tool for setting winter maintenance standards.

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APPENDIX A

LEVEL OF SERVICE BY YEAR

LEVEL OF SERVICE
BY YEAR

FA	YEAR	LM1	LM2	LM3	LM4	LM5	TLM	LS
120	8283	0	41	107	0	0	148	3.28
120	8384	0	41	107	0	0	148	3.28
120	8485	0	41	107	0	0	148	3.28
120	8586	0	41	107	0	0	148	3.28
120	8687	0	126	22	0	0	148	3.85
120	8788	0	126	22	0	0	148	3.85
120	8889	0	126	22	0	0	148	3.85
130	8283	0	230	79	0	0	309	3.74
130	8384	0	230	79	0	0	309	3.74
130	8485	0	230	79	0	0	309	3.74
130	8586	0	230	79	0	0	309	3.74
130	8687	0	230	79	0	0	309	3.74
130	8788	0	230	79	0	0	309	3.74
130	8889	0	230	79	0	0	309	3.74
140	8283	151	0	13	0	0	164	4.84
140	8384	151	0	13	0	0	164	4.84
140	8485	151	0	13	0	0	164	4.84
140	8586	151	0	13	0	0	164	4.84
140	8687	151	0	13	0	0	164	4.84
140	8788	151	0	13	0	0	164	4.84
140	8889	151	0	13	0	0	164	4.84
150	8283	0	173	84	0	0	257	3.67
150	8384	0	173	84	0	0	257	3.67
150	8485	0	173	84	0	0	257	3.67
150	8586	0	173	84	0	0	257	3.67
150	8687	29	145	84	0	0	257	3.80
150	8788	29	145	84	0	0	257	3.80
150	8889	29	145	84	0	0	257	3.80
160	8283	86	87	65	0	0	238	4.09
160	8384	86	87	65	0	0	238	4.09
160	8485	86	87	65	0	0	238	4.09
160	8586	86	87	65	0	0	238	4.09
160	8687	103	71	65	0	0	238	4.18
160	8788	103	71	65	0	0	238	4.18
160	8889	103	71	65	0	0	238	4.18
170	8283	187	38	96	0	0	321	4.28
170	8384	187	38	96	0	0	321	4.28
170	8485	187	38	96	0	0	321	4.28
170	8586	187	38	96	0	0	321	4.28
170	8687	187	38	96	0	0	321	4.28
170	8788	187	38	96	0	0	321	4.28
170	8889	187	38	96	0	0	321	4.28

LEVEL OF SERVICE
BY YEAR

FA	YEAR	LM1	LM2	LM3	LM4	LM5	TLM	LS
220	8283	93	14	139	0	0	245	3.83
220	8384	93	14	139	0	0	245	3.83
220	8485	93	14	139	0	0	245	3.83
220	8586	93	14	139	0	0	245	3.83
220	8687	93	14	139	0	0	245	3.83
220	8788	93	14	139	0	0	245	3.83
220	8889	93	14	139	0	0	245	3.83
240	8283	79	49	111	0	0	239	3.87
240	8384	79	49	111	0	0	239	3.87
240	8485	79	49	111	0	0	239	3.87
240	8586	79	49	111	0	0	239	3.87
240	8687	79	49	111	0	0	239	3.87
240	8788	79	49	111	0	0	239	3.87
240	8889	79	49	111	0	0	239	3.87
250	8283	0	111	103	15	0	229	3.42
250	8384	0	111	103	15	0	229	3.42
250	8485	0	111	103	15	0	229	3.42
250	8586	0	111	103	15	0	229	3.42
250	8687	0	111	103	15	0	229	3.42
250	8788	0	111	103	15	0	229	3.42
250	8889	0	111	103	15	0	229	3.42
260	8283	0	201	30	0	0	231	3.87
260	8384	0	201	30	0	0	231	3.87
260	8485	0	201	30	0	0	231	3.87
260	8586	0	201	30	0	0	231	3.87
260	8687	0	201	30	0	0	231	3.87
260	8788	0	201	30	0	0	231	3.87
260	8889	0	201	30	0	0	231	3.87
270	8283	50	67	103	0	0	219	3.78
270	8384	50	67	103	0	0	219	3.78
270	8485	50	67	103	0	0	219	3.78
270	8586	50	67	103	0	0	219	3.78
270	8687	109	8	103	0	0	219	4.05
270	8788	109	8	103	0	0	219	4.05
270	8889	109	8	103	0	0	219	4.05
290	8283	0	139	120	0	0	258	3.55
290	8384	0	139	120	0	0	258	3.55
290	8485	0	139	120	0	0	258	3.55
290	8586	0	139	120	0	0	258	3.55
290	8687	0	139	120	0	0	258	3.55
290	8788	0	139	120	0	0	258	3.55
290	8889	0	139	120	0	0	258	3.55

LEVEL OF SERVICE
BY YEAR

FA	YEAR	LM1	LM2	LM3	LM4	LM5	TLM	LS
320	8283	0	223	69	0	0	292	3.76
320	8384	0	223	69	0	0	292	3.76
320	8485	0	223	69	0	0	292	3.76
320	8586	0	223	69	0	0	292	3.76
320	8687	0	223	69	0	0	292	3.76
320	8788	0	223	69	0	0	292	3.76
320	8889	0	223	69	0	0	292	3.76
330	8283	72	162	62	0	0	296	4.03
330	8384	72	162	62	0	0	296	4.03
330	8485	72	162	62	0	0	296	4.03
330	8586	72	162	62	0	0	296	4.03
330	8687	87	147	62	0	0	296	4.08
330	8788	87	147	62	0	0	296	4.08
330	8889	87	147	62	0	0	296	4.08
340	8283	192	137	0	0	0	330	4.57
340	8384	192	137	0	0	0	330	4.57
340	8485	192	137	0	0	0	330	4.57
340	8586	192	137	0	0	0	330	4.57
340	8687	192	137	0	0	0	330	4.57
340	8788	192	137	0	0	0	330	4.57
340	8889	192	137	0	0	0	330	4.57
350	8283	256	0	117	256	0	628	3.41
350	8384	256	64	53	256	0	628	3.51
350	8485	256	64	53	256	0	628	3.51
350	8586	256	64	53	256	0	628	3.51
350	8687	256	64	53	256	0	628	3.51
350	8788	256	64	53	256	0	628	3.51
350	8889	256	64	53	256	0	628	3.51
370	8283	143	196	48	92	0	479	3.81
370	8384	143	196	48	92	0	479	3.81
370	8485	143	196	48	92	0	479	3.81
370	8586	143	196	48	92	0	479	3.81
370	8687	143	244	13	79	0	479	3.94
370	8788	143	244	13	79	0	479	3.94
370	8889	143	244	13	79	0	479	3.94
380	8283	0	178	30	0	0	208	3.86
380	8384	0	178	30	0	0	208	3.86
380	8485	0	178	30	0	0	208	3.86
380	8586	0	178	30	0	0	208	3.86
380	8687	0	178	30	0	0	208	3.86
380	8788	0	178	30	0	0	208	3.86
380	8889	0	178	30	0	0	208	3.86

LEVEL OF SERVICE
BY YEAR

FA	YEAR	LM1	LM2	LM3	LM4	LM5	TLM	LS
390	8283	0	4	17	78	67	167	1.74
390	8384	0	4	17	78	67	167	1.74
390	8485	0	4	17	78	67	167	1.74
390	8586	0	4	17	78	67	167	1.74
390	8687	0	4	163	0	0	167	3.02
390	8788	0	4	163	0	0	167	3.02
390	8889	0	4	163	0	0	167	3.02
430	8283	477	63	229	0	0	769	4.32
430	8384	477	63	229	0	0	769	4.32
430	8485	477	86	206	0	0	769	4.35
430	8586	477	86	206	0	0	769	4.35
430	8687	477	86	206	0	0	769	4.35
430	8788	477	86	206	0	0	769	4.35
430	8889	477	86	206	0	0	769	4.35
450	8283	0	219	329	0	0	549	3.39
450	8384	0	348	201	0	0	549	3.63
450	8485	0	348	201	0	0	549	3.63
450	8586	0	348	201	0	0	549	3.63
450	8687	0	348	201	0	0	549	3.63
450	8788	0	348	201	0	0	549	3.63
450	8889	0	348	201	0	0	549	3.63
460	8283	316	45	126	0	0	488	4.38
460	8384	316	45	126	0	0	488	4.38
460	8485	316	45	126	0	0	488	4.38
460	8586	316	45	126	0	0	488	4.38
460	8687	332	29	126	0	0	488	4.41
460	8788	332	29	126	0	0	488	4.41
460	8889	332	29	126	0	0	488	4.41
480	8283	38	32	178	0	40	289	3.09
480	8384	38	32	178	0	40	289	3.09
480	8485	38	32	178	0	40	289	3.09
480	8586	38	32	178	0	40	289	3.09
480	8687	38	32	218	0	0	289	3.36
480	8788	38	32	218	0	0	289	3.36
480	8889	38	32	218	0	0	289	3.36
490	8283	101	164	36	0	0	302	4.20
490	8384	101	164	36	0	0	302	4.20
490	8485	101	164	36	0	0	302	4.20
490	8586	101	164	36	0	0	302	4.20
490	8687	101	164	36	0	0	302	4.20
490	8788	101	164	36	0	0	302	4.20
490	8889	101	164	36	0	0	302	4.20

LEVEL OF SERVICE
BY YEAR

FA	YEAR	LM1	LM2	LM3	LM4	LM5	TLM	LS
530	8283	192	0	105	35	0	332	4.05
530	8384	192	0	105	35	0	332	4.05
530	8485	192	0	105	35	0	332	4.05
530	8586	192	0	105	35	0	332	4.05
530	8687	192	0	104	0	0	296	4.30
530	8788	192	0	104	0	0	296	4.30
530	8889	192	0	104	0	0	296	4.30
540	8283	272	33	0	0	0	306	4.88
540	8384	272	33	0	0	0	306	4.88
540	8485	272	33	0	0	0	306	4.88
540	8586	272	33	0	0	0	306	4.88
540	8687	272	33	0	0	0	306	4.88
540	8788	272	33	0	0	0	306	4.88
540	8889	272	33	0	0	0	306	4.88
550	8283	0	72	130	0	0	202	3.36
550	8384	0	72	130	0	0	202	3.36
550	8485	0	72	130	0	0	202	3.36
550	8586	0	72	130	0	0	202	3.36
550	8687	0	22	165	0	0	187	3.12
550	8788	0	22	165	0	0	187	3.12
550	8889	0	22	165	0	0	187	3.12
560	8283	167	155	0	0	0	322	4.52
560	8384	167	155	0	0	0	322	4.52
560	8485	167	155	0	0	0	322	4.52
560	8586	167	155	0	0	0	322	4.52
560	8687	167	155	0	0	0	322	4.52
560	8788	167	155	0	0	0	322	4.52
560	8889	167	155	0	0	0	322	4.52
570	8283	153	51	60	0	0	264	4.35
570	8384	153	51	60	0	0	264	4.35
570	8485	153	51	60	0	0	264	4.35
570	8586	153	51	60	0	0	264	4.35
570	8687	153	51	25	35	0	264	4.22
570	8788	153	51	25	35	0	264	4.22
570	8889	153	51	25	35	0	264	4.22
580	8283	0	142	143	0	0	285	3.50
580	8384	0	142	143	0	0	285	3.50
580	8485	0	142	143	0	0	285	3.50
580	8586	0	142	143	0	0	285	3.50
580	8687	0	102	183	0	0	285	3.36
580	8788	0	102	183	0	0	285	3.36
580	8889	0	102	183	0	0	285	3.36

LEVEL OF SERVICE
BY YEAR

FA	YEAR	LM1	LM2	LM3	LM4	LM5	TLM	LS
590	8283	0	74	120	0	0	194	3.38
590	8384	0	74	120	0	0	194	3.38
590	8485	0	74	120	0	0	194	3.38
590	8586	0	74	120	0	0	194	3.38
590	8687	0	74	120	0	0	194	3.38
590	8788	0	74	120	0	0	194	3.38
590	8889	0	74	120	0	0	194	3.38
640	8283	0	113	25	72	0	210	3.20
640	8384	0	113	25	72	0	210	3.20
640	8485	0	113	25	72	0	210	3.20
640	8586	0	113	25	72	0	210	3.20
640	8687	0	113	0	97	0	210	3.08
640	8788	0	113	0	97	0	210	3.08
640	8889	0	113	0	97	0	210	3.08
650	8283	153	114	82	22	0	371	4.07
650	8384	153	114	82	22	0	371	4.07
650	8485	153	114	82	22	0	371	4.07
650	8586	153	114	82	22	0	371	4.07
650	8687	153	114	82	22	0	371	4.07
650	8788	153	114	82	22	0	371	4.07
650	8889	153	114	82	22	0	371	4.07
660	8283	0	294	56	147	0	497	3.30
660	8384	0	294	175	28	0	497	3.54
660	8485	0	294	175	28	0	497	3.54
660	8586	0	294	175	28	0	497	3.54
660	8687	0	294	175	28	0	497	3.54
660	8788	0	294	175	28	0	497	3.54
660	8889	0	294	175	28	0	497	3.54
670	8283	0	362	76	10	0	448	3.79
670	8384	0	362	76	10	0	448	3.79
670	8485	0	362	49	37	0	448	3.73
670	8586	0	362	49	37	0	448	3.73
670	8687	0	362	0	86	0	448	3.62
670	8788	0	362	0	86	0	448	3.62
670	8889	0	362	0	86	0	448	3.62
680	8283	49	193	78	140	0	460	3.33
680	8384	49	193	78	140	0	460	3.33
680	8485	49	193	78	140	0	460	3.33
680	8586	49	193	78	140	0	460	3.33
680	8687	49	193	78	140	0	460	3.33
680	8788	49	193	78	140	0	460	3.33
680	8889	49	193	78	140	0	460	3.33

LEVEL OF SERVICE
BY YEAR

FA	YEAR	LM1	LM2	LM3	LM4	LM5	TLM	LS
690	8283	191	243	58	0	0	492	4.27
690	8384	191	243	58	0	0	492	4.27
690	8485	191	243	58	0	0	492	4.27
690	8586	191	243	58	0	0	492	4.27
690	8687	191	243	58	0	0	492	4.27
690	8788	191	243	58	0	0	492	4.27
690	8889	191	243	58	0	0	492	4.27

APPENDIX B

AVERAGE STORM HOURS (ASH) FOR VARIOUS CUTOFF LEVELS AND COMPARISON OF OLD AND UPDATED ASH VALUES

Table B-1

ASH Values at Various Cutoff Levels
Average over the years

FA	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
120	65.3	63.9	59.7	55.6	53.9
130	135.7	130.4	125.7	117.7	112.7
140	96.1	94.6	90.1	85.2	81.1
150	118.7	115.3	110.9	105.6	100.0
160	109.3	105.4	100.8	94.9	90.5
170	143.8	138.6	130.5	125.6	119.1
220	99.5	97.6	92.8	87.0	81.2
240	99.5	98.2	94.2	89.8	85.2
250	81.7	77.6	73.9	68.5	65.0
260	98.6	95.7	91.7	87.4	83.8
270	77.2	75.4	71.4	67.4	62.8
290	76.6	73.0	69.2	65.7	63.6
320	95.0	91.6	86.1	79.6	75.1
330	96.7	92.6	88.5	83.4	79.8
340	103.7	100.3	97.8	91.9	84.1
350	105.3	101.6	95.9	88.4	83.8
370	107.2	105.3	99.4	94.7	89.5
380	76.1	74.2	70.3	66.1	62.8
390	71.8	68.7	65.1	61.5	58.2
430	169.6	164.3	155.1	144.3	137.7
450	135.8	131.4	123.1	117.8	111.9
460	105.7	101.3	96.0	89.0	85.1
480	88.7	86.1	80.3	74.4	70.3
490	91.7	89.9	88.0	82.7	79.3
530	117.4	113.4	108.7	101.9	95.8
540	108.1	102.9	96.8	90.5	86.3
550	82.0	77.2	74.2	69.3	63.6
560	84.2	80.4	76.3	70.4	66.2
570	91.7	90.5	85.8	79.5	75.0
580	100.1	96.3	91.7	87.6	83.1
590	85.2	82.0	78.2	73.9	69.2
640	107.2	100.6	95.2	90.4	86.2
650	114.4	111.1	105.5	98.9	93.7
660	73.9	71.4	68.7	64.4	61.3
670	61.1	58.2	55.2	51.7	48.6
680	86.3	83.7	75.7	70.1	65.8
690	155.1	148.7	141.1	125.8	119.1

Table B-2

ASH Values at Various Cutoff Levels
by FA and Year

FA=120

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	62.7	61.1	57.8	52.9	51.1
8384	55.2	55.2	52.5	49.5	49.5
8485	74.0	69.9	65.5	61.7	59.5
8586	78.4	76.4	70.1	66.5	64.2
8687	67.2	67.2	58.5	54.0	52.1
8788	51.4	51.4	49.4	45.4	43.9
8889	68.5	65.7	63.8	59.1	57.2

FA=130

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	155.3	139.8	139.8	133.6	130.9
8384	123.4	118.4	115.8	107.8	100.0
8485	154.7	151.9	146.6	128.6	124.6
8586	134.9	130.5	126.6	118.5	111.5
8687	105.9	103.9	95.5	91.8	89.3
8788	125.3	120.5	112.5	108.8	102.4
8889	150.5	147.8	142.8	135.0	130.4

FA=140

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	86.5	83.0	76.8	72.9	69.9
8384	105.6	105.6	97.2	89.1	84.2
8485	101.5	99.8	94.3	87.3	83.9
8586	96.5	95.6	91.4	86.3	82.5
8687	76.3	75.4	73.6	68.9	64.3
8788	80.5	76.9	75.6	72.7	68.3
8889	125.7	125.7	121.8	119.2	114.9

FA=150

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	108.7	103.7	100.9	100.9	97.1
8384	100.3	100.3	95.2	88.3	85.1
8485	144.8	142.8	133.4	123.7	115.4
8586	121.3	117.1	112.2	108.3	100.3
8687	85.4	79.7	76.8	73.0	68.0
8788	101.2	98.9	96.5	88.9	85.3
8889	169.1	164.6	161.1	156.0	148.9

Table B-2

ASH Values at Various Cutoff Levels
by FA and Year

FA=160

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	119.6	107.8	101.1	92.7	87.6
8384	88.3	86.8	83.7	77.1	73.5
8485	114.5	110.6	107.1	101.0	93.9
8586	115.8	112.8	106.5	103.0	99.3
8687	81.7	81.7	76.8	75.4	68.8
8788	103.0	100.5	97.9	93.2	91.8
8889	142.0	137.4	132.9	122.2	118.7

FA=170

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	134.2	124.8	116.2	108.5	104.5
8384	118.0	116.2	109.2	104.8	97.0
8485	170.1	165.7	152.5	150.2	144.6
8586	154.5	149.3	144.0	139.1	131.6
8687	110.9	107.2	98.3	88.6	85.5
8788	128.6	124.9	116.8	113.6	106.2
8889	190.5	182.4	176.7	174.4	163.8

FA=220

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	79.3	79.3	79.3	76.1	63.8
8384	101.4	101.4	101.4	91.5	84.3
8485	122.2	119.7	114.4	107.3	104.8
8586	88.1	85.9	84.8	80.7	78.2
8687	88.2	82.7	78.4	71.0	65.3
8788	85.3	85.3	78.2	75.9	69.9
8889	132.4	128.9	112.9	106.4	102.2

FA=240

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	91.2	89.5	86.1	84.2	82.1
8384	90.3	88.6	86.8	83.3	74.9
8485	120.7	119.1	119.1	111.5	106.5
8586	101.8	101.8	97.1	92.6	86.1
8687	80.2	80.2	78.0	75.6	73.2
8788	93.4	91.0	83.9	80.6	76.1
8889	118.9	117.3	108.7	100.7	97.8

Table B-2

ASH Values at Various Cutoff Levels
by FA and Year

FA=250

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	48.5	48.5	47.3	44.1	42.2
8384	84.4	79.8	77.9	69.3	63.6
8485	117.0	110.9	103.2	95.7	87.5
8586	75.5	74.3	69.2	65.6	63.1
8687	65.8	61.0	59.0	55.2	53.5
8788	80.0	69.5	65.5	57.1	56.0
8889	100.5	99.1	95.2	92.3	89.2

FA=260

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	87.4	87.4	79.6	78.2	74.2
8384	93.6	92.5	90.1	86.1	84.7
8485	96.9	96.0	91.5	88.2	83.4
8586	87.6	85.5	81.4	74.4	71.4
8687	84.9	80.2	76.6	69.3	64.9
8788	114.4	107.2	104.0	101.2	97.4
8889	125.1	121.0	118.9	114.1	110.5

FA=270

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	72.4	72.4	69.6	60.8	56.5
8384	80.3	79.0	77.5	76.0	70.1
8485	89.3	86.1	83.1	76.9	71.8
8586	77.2	73.9	71.9	68.8	64.8
8687	64.7	64.7	57.0	52.0	47.3
8788	65.6	64.3	59.6	57.0	55.2
8889	90.9	87.3	81.5	80.2	74.2

FA=290

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	60.8	58.3	54.0	54.0	51.9
8384	80.3	77.9	74.3	71.0	69.0
8485	78.2	76.3	73.3	70.4	69.3
8586	69.3	66.6	63.4	61.3	56.2
8687	62.6	62.6	62.6	59.9	57.1
8788	89.8	78.9	72.1	64.8	64.8
8889	95.4	90.3	84.5	78.3	76.7

Table B-2

ASH Values at Various Cutoff Levels
by FA and Year

FA=320

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	87.5	82.8	82.2	77.4	73.2
8384	89.2	87.1	82.7	78.1	74.9
8485	101.6	97.7	91.4	80.4	75.2
8586	119.2	110.9	95.9	89.0	83.6
8687	74.8	74.8	72.9	64.0	58.4
8788	90.7	87.1	82.2	77.5	73.6
8889	101.8	101.1	95.7	90.9	86.8

FA=330

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	95.3	89.0	84.1	81.9	81.9
8384	96.1	91.3	85.8	77.7	74.3
8485	88.7	85.1	82.1	75.1	68.5
8586	92.8	89.8	88.5	85.8	84.4
8687	93.2	93.2	88.3	83.7	76.2
8788	90.0	83.6	83.6	72.2	70.7
8889	121.1	115.9	107.0	107.0	102.9

FA=340

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	101.2	101.2	94.7	89.3	79.9
8384	134.9	130.9	128.6	123.8	110.4
8485	77.7	75.3	74.0	69.0	64.6
8586	103.8	102.0	98.5	96.2	90.5
8687	72.6	72.6	72.6	65.5	57.0
8788	94.9	89.5	85.3	77.9	72.2
8889	141.1	130.8	130.8	121.6	114.0

FA=350

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	87.0	83.3	80.2	72.0	70.0
8384	133.2	129.2	118.3	114.7	111.9
8485	110.6	110.6	104.8	97.0	87.9
8586	160.5	153.3	137.4	120.5	113.4
8687	74.4	68.8	66.4	66.4	59.5
8788	79.3	76.8	76.8	67.5	65.8
8889	92.2	89.3	87.6	80.4	78.0

Table B-2

ASH Values at Various Cutoff Levels
by FA and Year

FA=370

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	90.5	87.1	87.1	87.1	82.4
8384	152.4	152.4	147.5	131.0	125.5
8485	86.0	84.5	81.5	75.9	74.4
8586	127.6	127.6	122.9	118.7	107.1
8687	80.5	80.5	63.4	61.2	56.6
8788	79.3	77.9	74.6	74.6	68.6
8889	134.2	126.9	119.1	114.3	111.6

FA=380

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	79.4	77.1	73.0	67.7	67.0
8384	83.1	80.6	74.4	68.5	66.9
8485	84.3	83.4	78.6	74.8	69.9
8586	81.3	79.4	75.1	69.4	65.9
8687	49.5	47.6	46.5	45.8	41.5
8788	69.6	68.3	64.8	60.1	55.7
8889	85.7	83.1	80.0	76.3	72.4

FA=390

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	63.0	61.3	59.5	54.0	52.5
8384	54.9	52.2	50.5	48.3	46.0
8485	75.4	73.6	70.9	68.4	63.7
8586	76.3	71.5	67.0	62.5	58.1
8687	59.0	55.6	52.8	50.8	48.3
8788	92.0	86.1	81.0	77.0	70.4
8889	81.8	80.7	74.2	69.2	68.4

FA=430

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	180.4	163.2	149.7	149.7	139.8
8384	190.7	182.9	173.2	163.5	157.4
8485	170.3	170.3	149.3	130.2	121.2
8586	203.8	203.8	196.0	178.6	165.7
8687	134.0	134.0	134.0	127.5	127.5
8788	161.2	151.3	145.4	131.4	128.3
8889	147.1	144.7	138.1	129.6	124.3

Table B-2

ASH Values at Various Cutoff Levels
by FA and Year

FA=450

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	125.4	122.7	119.7	117.1	109.1
8384	169.1	165.6	151.1	151.1	151.1
8485	144.6	141.8	134.4	125.9	119.9
8586	137.3	132.8	128.1	124.0	111.1
8687	104.8	95.0	90.4	84.7	80.3
8788	110.0	110.0	91.8	88.2	84.7
8889	159.3	152.2	145.9	133.4	127.3

FA=460

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	101.7	101.7	85.6	80.3	80.3
8384	117.1	113.9	110.9	105.5	98.0
8485	90.7	86.0	75.2	73.1	69.9
8586	126.0	126.0	126.0	109.4	99.3
8687	87.0	80.0	80.0	71.8	71.8
8788	103.0	87.0	79.3	72.2	65.6
8889	114.8	114.8	114.8	110.6	110.6

FA=480

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	118.6	113.6	105.6	96.0	88.4
8384	88.0	88.0	79.3	73.5	68.6
8485	93.9	91.6	80.6	77.0	71.8
8586	87.1	82.7	77.3	72.3	71.2
8687	57.7	56.9	55.3	52.7	50.5
8788	79.6	78.1	74.1	67.0	63.1
8889	96.1	91.8	89.7	82.2	78.5

FA=490

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	47.3	45.5	43.4	40.3	40.3
8384	98.9	96.1	93.8	87.0	84.8
8485	95.7	93.3	89.2	83.7	80.2
8586	129.3	125.1	125.1	110.2	100.3
8687	87.4	87.4	87.4	87.4	81.3
8788	88.3	87.0	84.0	84.0	81.9
8889	95.1	95.1	93.0	86.4	86.4

Table B-2

ASH Values at Various Cutoff Levels
by FA and Year

FA=530

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	97.2	97.2	95.5	90.3	85.4
8384	142.7	137.2	129.2	118.2	116.1
8485	130.5	113.7	104.5	98.2	88.6
8586	121.3	118.8	114.1	106.3	101.9
8687	84.2	84.2	81.3	78.5	73.4
8788	119.7	116.9	110.2	108.1	98.2
8889	126.1	126.1	126.1	113.9	106.9

FA=540

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	129.7	117.3	99.8	93.0	90.0
8384	122.0	118.2	118.2	111.6	105.7
8485	126.2	119.5	109.9	100.0	92.9
8586	102.4	96.2	92.6	91.0	88.8
8687	72.2	69.0	69.0	69.0	64.7
8788	96.0	92.1	92.1	79.7	77.6
8889	108.2	108.2	96.2	89.0	84.6

FA=550

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	62.7	60.9	57.1	55.8	51.7
8384	76.5	75.5	73.5	66.4	62.1
8485	81.4	76.8	73.2	65.1	63.1
8586	78.4	78.4	73.3	66.5	65.3
8687	61.2	59.9	59.9	58.2	58.2
8788	118.3	101.0	101.0	94.9	72.1
8889	95.3	87.7	81.2	78.5	72.8

FA=560

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	78.3	78.3	68.2	64.5	61.1
8384	79.0	77.6	73.0	68.1	66.9
8485	137.2	120.1	120.1	111.8	99.3
8586	87.0	87.0	87.0	79.0	73.6
8687	56.8	56.8	56.8	53.4	50.5
8788	64.7	64.7	57.2	51.0	49.2
8889	86.5	78.3	71.6	64.8	62.6

Table B-2

ASH Values at Various Cutoff Levels
by FA and Year

FA=570

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	85.5	85.5	75.3	71.4	58.4
8384	107.3	101.5	99.0	87.2	85.8
8485	77.5	75.0	68.6	64.2	61.5
8586	131.3	131.3	123.9	112.8	112.8
8687	62.7	62.7	62.7	62.7	62.7
8788	75.3	75.3	68.4	65.9	63.2
8889	102.5	102.5	102.5	92.1	80.5

FA=580

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	101.9	101.9	96.6	92.3	89.5
8384	120.8	116.6	110.4	108.7	104.1
8485	102.7	97.3	92.7	83.8	79.8
8586	122.6	112.6	105.6	102.0	93.4
8687	70.1	69.0	67.5	65.8	61.3
8788	89.2	87.7	84.9	79.2	75.6
8889	93.5	89.0	84.3	81.3	78.1

FA=590

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	77.9	76.6	71.0	68.9	65.4
8384	85.0	83.2	79.4	74.6	68.8
8485	88.3	84.4	79.4	76.3	70.5
8586	97.8	96.4	91.5	86.6	81.7
8687	66.9	64.2	61.5	58.0	54.9
8788	84.7	80.5	77.1	72.6	67.1
8889	96.0	89.1	87.5	80.0	75.7

FA=640

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	104.8	103.7	98.4	95.5	92.5
8384	95.4	91.3	88.5	85.0	78.5
8485	101.7	98.9	94.6	90.3	83.6
8586	116.6	113.1	111.9	103.4	99.9
8687	73.4	70.4	68.5	67.0	64.8
8788	97.9	93.5	87.6	82.2	77.6
8889	160.6	133.0	116.9	109.7	106.2

Table B-2

ASH Values at Various Cutoff Levels
by FA and Year

FA=650

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	90.8	87.5	85.3	78.8	76.3
8384	118.2	114.1	104.6	95.2	93.6
8485	147.2	142.9	128.9	119.8	110.9
8586	129.8	125.7	121.4	114.3	107.5
8687	77.6	75.8	74.1	74.1	69.4
8788	92.6	91.4	87.6	81.6	77.8
8889	144.4	140.6	136.7	128.6	120.1

FA=660

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	79.4	74.4	72.0	68.8	66.7
8384	89.2	85.4	82.6	80.8	76.5
8485	66.0	64.3	60.4	58.1	55.7
8586	74.9	72.9	70.8	64.8	62.1
8687	47.3	45.9	44.7	42.6	39.4
8788	70.7	67.1	64.4	61.5	59.6
8889	89.8	89.8	86.4	74.5	69.0

FA=670

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	81.1	74.1	70.7	66.1	60.6
8384	54.7	53.6	48.2	45.8	43.4
8485	86.1	83.1	80.2	74.8	72.2
8586	56.5	54.0	51.2	48.7	44.7
8687	45.5	42.4	42.4	39.7	39.7
8788	44.0	40.6	38.2	34.5	31.1
8889	59.4	59.4	55.7	52.6	48.2

FA=680

YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	110.0	110.0	110.0	88.9	76.7
8384	75.4	74.0	66.6	65.0	63.6
8485	89.5	82.0	78.9	77.4	74.2
8586	74.6	70.4	66.1	61.6	59.6
8687	104.5	104.5	68.4	59.9	56.8
8788	50.4	49.0	47.7	47.7	43.6
8889	99.9	95.8	92.1	90.0	86.3

Table B-2

ASH Values at Various Cutoff Levels
by FA and Year

FA=690 YEAR	K=1.65	K=1.50	K=1.28	K=1.04	K=0.84
8283	115.7	112.4	111.0	109.4	105.9
8384	147.2	142.1	142.1	121.0	113.2
8485	196.8	192.3	181.1	161.2	148.4
8586	234.7	214.1	188.4	146.5	135.8
8687	93.6	88.1	85.9	79.6	75.6
8788	108.0	105.9	101.9	95.3	93.7
8889	189.9	185.7	177.6	167.5	161.1

Chart B-1

Comparison of Old and Updated ASH Values

DIST=1

BAR CHART OF ASH

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FA   ASH                                                                   ASH
         |
120  NEW |**************************                                      63.8
     OLD |**************************                                      65.9
         |
130  NEW |****************************************************           130.3
     OLD |***************************************************            128.3
         |
140  NEW |**************************************                          94.5
     OLD |*************************************                           91.8
         |
150  NEW |**********************************************                 115.2
     OLD |*******************************************                    108.6
         |
160  NEW |******************************************                     105.3
     OLD |****************************************                        99.7
         |
170  NEW |*******************************************************        138.6
     OLD |*****************************************************          133.2
         |
         --------+--------+--------+--------+--------+--------+--------+--------+
               20.0     40.0     60.0     80.0    100.0    120.0    140.0    160.0

                                        ASH
```

Chart B-2

Comparison of Old and Updated ASH Values

DIST=2

BAR CHART OF ASH

```
                                                                              ASH
FA    ASH   |
            |
220   NEW   |***************************************                          97.5
      OLD   |*************************************                            93.1
            |
240   NEW   |***************************************                          98.2
      OLD   |**************************************                           95.8
            |
250   NEW   |*******************************                                  77.5
      OLD   |******************************                                   74.8
            |
260   NEW   |**************************************                           95.6
      OLD   |***********************************                              87.5
            |
270   NEW   |******************************                                   75.3
      OLD   |******************************                                   75.0
            |
290   NEW   |*****************************                                    72.9
      OLD   |***************************                                      68.3
            |
            --------+-------+-------+-------+-------+-------+-------+-------+
                  20.0    40.0    60.0    80.0   100.0   120.0   140.0   160.0

                                      ASH
```

Chart B-3

Comparison of Old and Updated ASH Values

DIST=3

BAR CHART OF ASH

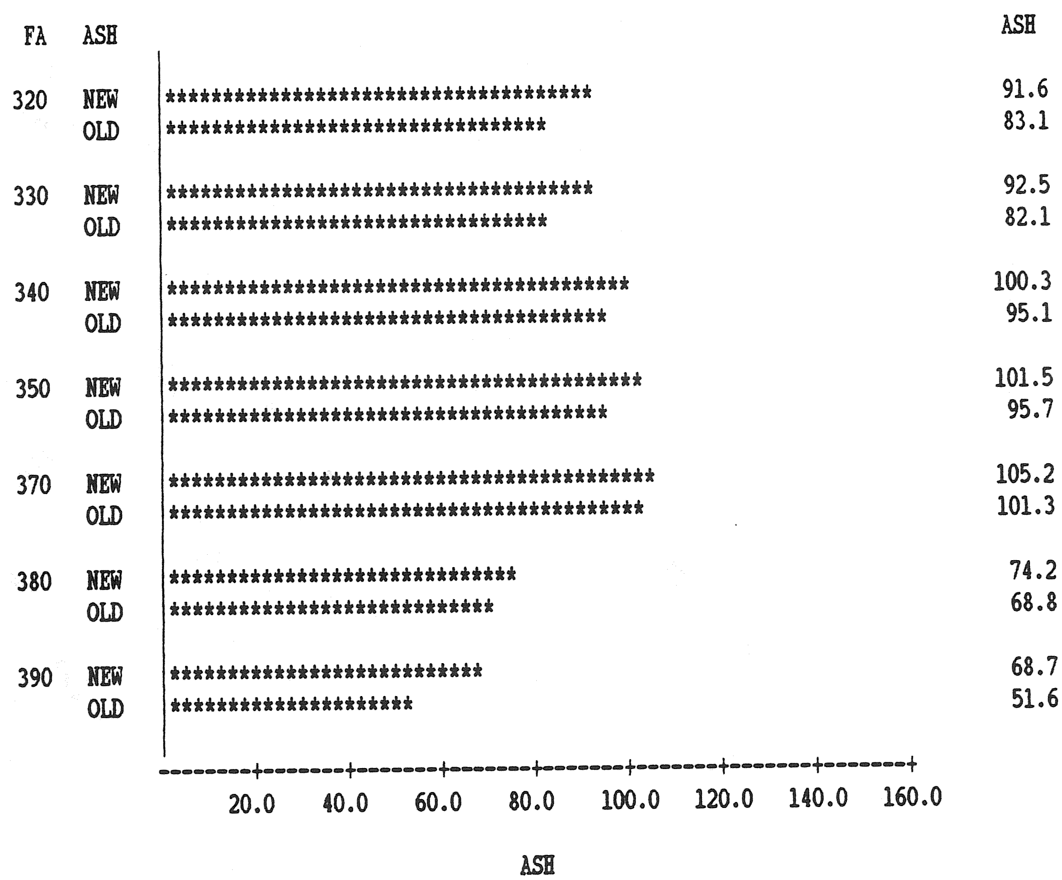

Chart B-4

Comparison of Old and Updated ASH Values

DIST=4

BAR CHART OF ASH

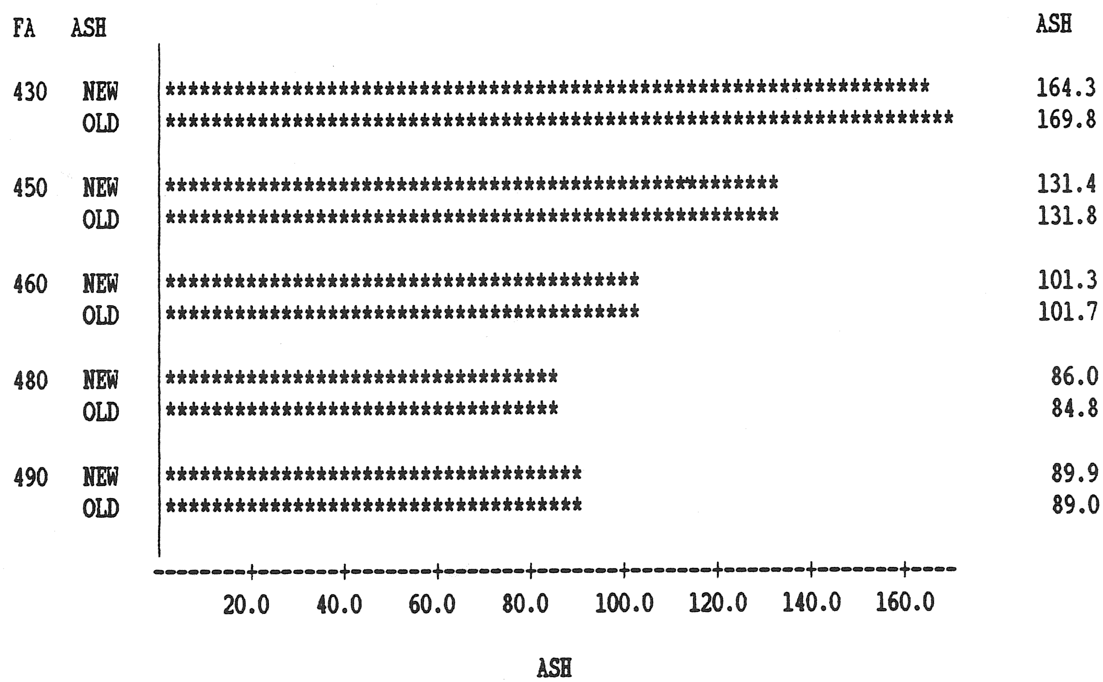

Chart B-5

Comparison of Old and Updated ASH Values

DIST=5

BAR CHART OF ASH

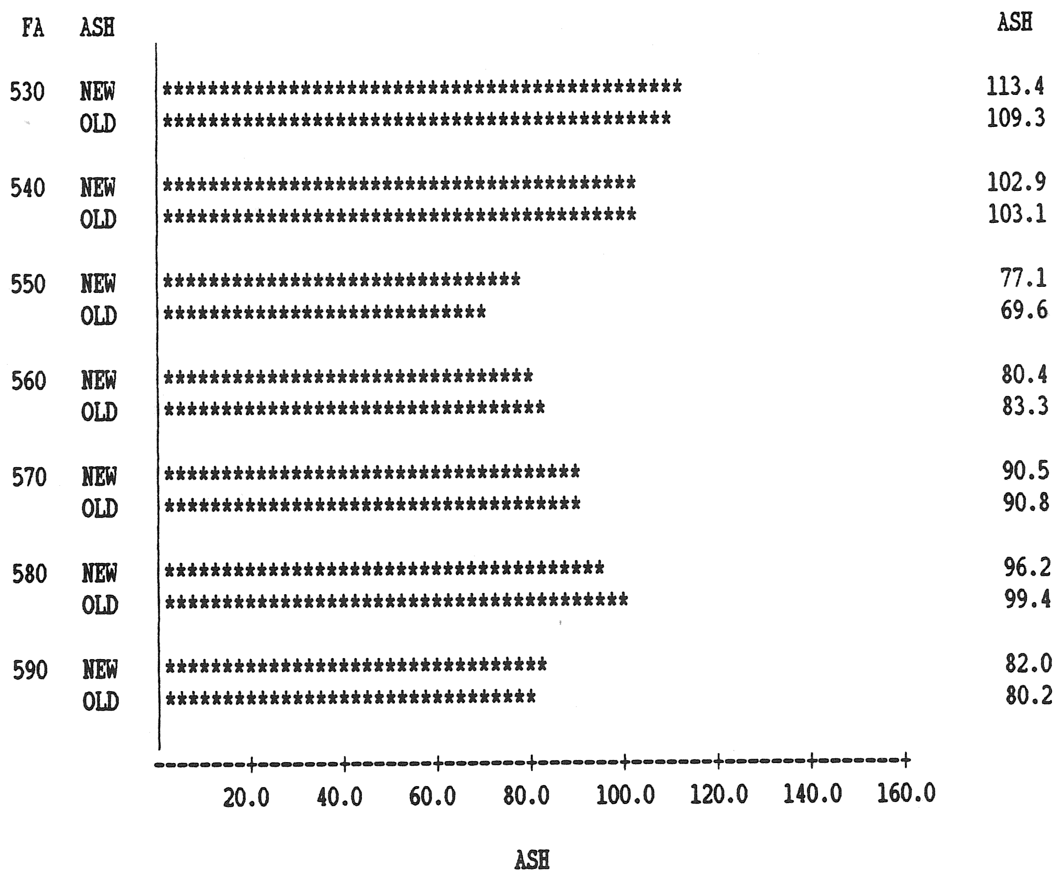

Chart B-6

Comparison of Old and Updated ASH Values

DIST=6

BAR CHART OF ASH

```
FA   ASH                                                                          ASH

640  NEW  |****************************************                              100.5
     OLD  |**************************************                                 94.5

650  NEW  |********************************************                          111.1
     OLD  |******************************************                            105.4

660  NEW  |*****************************                                          71.4
     OLD  |****************************                                           68.8

670  NEW  |***********************                                                58.1
     OLD  |**********************                                                 54.3

680  NEW  |*********************************                                      83.6
     OLD  |***************************                                            68.1

690  NEW  |***********************************************************           148.6
     OLD  |*********************************************************             143.1
          |
          --------+-------+-------+-------+-------+-------+-------+-------+
                20.0    40.0    60.0    80.0   100.0   120.0   140.0   160.0

                                        ASH
```

APPENDIX C

SUMMARY OF TRANSIENT VARIABLES BY FA AND YEAR

Summary of Transient Variables
by FA and year

FA=120

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	428.0	-109.3	7	168157	107083
8384	497.0	-40.3	9	168157	97834
8485	559.0	21.7	8	168157	158067
8586	688.0	150.7	9	168157	145443
8687	403.0	-134.3	6	168157	151394
8788	463.0	-74.3	9	168157	104992
8889	723.0	185.7	11	168157	148944

FA=130

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1817.0	215.6	13	286481	314279
8384	1302.0	-299.4	11	286481	242442
8485	1823.0	221.6	12	286481	294318
8586	1435.0	-166.4	11	286481	272840
8687	1143.0	-458.4	11	286481	253463
8788	1325.0	-276.4	11	286481	247509
8889	2365.0	763.6	16	286481	408882

FA=140

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1079.0	-240.4	13	265450	258514
8384	1056.0	-263.4	10	265450	255756
8485	1397.0	77.6	14	265450	282904
8586	1434.0	114.6	15	265450	267505
8687	980.0	-339.4	13	265450	273344
8788	1153.0	-166.4	15	265450	327986
8889	2137.0	817.6	17	265450	431690

FA=150

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1244.0	-418.4	12	299346	213712
8384	1203.0	-459.4	12	299346	268037
8485	1999.0	336.6	14	299346	348787
8586	1873.0	210.6	16	299346	365897
8687	1036.0	-626.4	13	299346	331118
8788	1484.0	-178.4	15	299346	329980
8889	2798.0	1135.6	17	299346	521584

Summary of Transient Variables
by FA and year

FA=160

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	862.0	-369.9	8	230355	163423
8384	867.5	-364.4	10	230355	196811
8485	1549.0	317.1	14	230355	261204
8586	1354.0	122.1	12	230355	315277
8687	899.0	-332.9	11	230355	242989
8788	1305.9	74.0	13	230355	263713
8889	1786.0	554.1	13	230355	378957

FA=170

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1372.7	-660.8	11	341747	227634
8384	1510.0	-523.5	13	341747	299039
8485	2485.0	451.5	15	341747	431089
8586	2389.0	355.5	16	341747	418168
8687	1072.0	-961.5	10	341747	303325
8788	2123.0	89.4	17	341747	390014
8889	3283.0	1249.5	18	341747	535459

FA=220

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	793.0	-310.1	10	204939	197405
8384	1115.3	12.2	11	204939	138506
8485	1676.0	572.9	14	204939	196789
8586	1288.0	184.9	15	204939	175797
8687	579.0	-524.1	7	204939	155862
8788	853.0	-250.1	10	204939	158990
8889	1417.7	314.5	11	204939	263783

FA=240

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1074.0	-110.9	12	194311	111588
8384	975.0	-209.9	11	194311	143511
8485	1786.0	601.1	15	194311	215267
8586	1222.0	37.1	12	194311	188430
8687	802.0	-382.9	10	194311	165649
8788	910.0	-274.9	10	194311	176852
8889	1525.0	340.1	13	194311	256401

Summary of Transient Variables
by FA and year

FA=250

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	534.0	-346.4	11	190690	76828
8384	877.7	-2.7	11	190690	107630
8485	1109.0	228.6	10	190690	157660
8586	891.0	10.6	12	190690	139087
8687	610.0	-270.4	10	190690	99020
8788	556.0	-324.4	8	190690	116471
8889	1585.0	704.6	16	190690	209366

FA=260

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1136.0	-467.3	13	258142	177554
8384	1572.2	-31.1	17	258142	208838
8485	1632.0	28.7	17	258142	242371
8586	1368.0	-235.3	16	258142	243948
8687	1043.0	-560.3	13	258142	266764
8788	1930.0	326.7	18	258142	321589
8889	2542.0	938.7	21	258142	373022

FA=270

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	579.0	-264.2	8	188912	92238
8384	1027.5	184.3	13	188912	147259
8485	1119.0	275.8	13	188912	167080
8586	1035.0	191.8	14	188912	156744
8687	388.0	-455.2	6	188912	132529
8788	707.0	-136.2	11	188912	150197
8889	1047.0	203.8	12	188912	191543

FA=290

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	408.0	-346.7	7	159675	80736
8384	1013.0	258.3	13	159675	151169
8485	992.0	237.3	13	159675	149732
8586	733.0	-21.7	11	159675	153579
8687	501.0	-253.7	8	159675	118171
8788	552.0	-202.7	7	159675	141788
8889	1084.0	329.3	12	159675	215166

Summary of Transient Variables
by FA and year

FA=320

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1574.0	387.2	19	246944	154852
8384	1393.0	206.2	16	246944	189817
8485	1172.0	-14.8	12	246944	192718
8586	887.0	-299.8	8	246944	214504
8687	748.0	-438.8	10	246944	156781
8788	1219.0	32.2	14	246944	186210
8889	1314.3	127.5	13	246944	274708

FA=330

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	801.0	17.2	9	131719	66789
8384	913.0	129.3	10	131719	103462
8485	510.7	-273.1	6	131719	90526
8586	1167.0	383.2	13	131719	118207
8687	466.0	-317.7	5	131719	98749
8788	585.0	-198.7	7	131719	107865
8889	1043.5	259.8	9	131719	169707

FA=340

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	607.1	-356.3	6	131342	82191
8384	1832.2	868.7	14	131342	188566
8485	903.4	-60.0	12	131342	141805
8586	1224.6	261.1	12	131342	184372
8687	290.3	-673.2	4	131342	73228
8788	447.5	-516.0	5	131342	114904
8889	1439.1	475.6	11	131342	249814

FA=350

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1000.0	-46.9	12	154912	135047
8384	1679.0	632.1	13	154912	227772
8485	1105.6	58.7	10	154912	169818
8586	1072.9	25.9	7	154912	206587
8687	619.0	-427.9	9	154912	108770
8788	691.5	-355.4	9	154912	119737
8889	1160.6	113.6	13	154912	203418

Summary of Transient Variables
by FA and year

FA=370

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	696.8	-5.6	8	136937	112832
8384	1219.3	516.8	8	136937	212320
8485	591.8	-110.6	7	136937	133270
8586	765.4	63.0	6	136937	185708
8687	161.0	-541.4	2	136937	108766
8788	467.5	-234.9	6	136937	108694
8889	1015.2	312.7	8	136937	187979

FA=380

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1155.9	46.7	15	149950	162878
8384	1128.9	19.7	14	149950	195102
8485	1333.9	224.6	16	149950	205539
8586	952.9	-156.3	12	149950	204737
8687	809.0	-300.3	17	149950	143451
8788	888.0	-221.3	13	149950	170741
8889	1496.1	386.9	18	149950	250804

FA=390

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	796.4	-117.1	13	165629	166475
8384	782.4	-131.1	15	165629	127290
8485	1177.1	263.6	16	165629	172969
8586	858.4	-55.1	12	165629	177305
8687	778.2	-135.3	14	165629	105987
8788	1033.7	120.2	12	165629	154835
8889	968.3	54.8	12	165629	236174

FA=430

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1469.2	-18.7	9	231491	181782
8384	2377.5	889.6	13	231491	315439
8485	1192.0	-295.9	7	231491	220251
8586	1630.0	142.1	8	231491	230666
8687	937.7	-550.2	7	231491	113558
8788	1362.0	-125.9	9	231491	192362
8889	1447.0	-40.9	10	231491	261168

Summary of Transient Variables
by FA and year

FA=450

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1472.3	214.4	12	193402	134141
8384	1822.0	564.1	11	193402	186386
8485	1560.0	302.1	11	193402	156147
8586	1062.0	-195.9	8	193402	123745
8687	665.0	-592.9	7	193402	76024
8788	550.0	-707.9	5	193402	99211
8889	1674.0	416.1	11	193402	228620

FA=460

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	305.0	-186.6	3	69219.1	46509
8384	1139.5	647.8	10	69219.1	134850
8485	344.0	-147.6	4	69219.1	89994
8586	630.0	138.4	5	69219.1	127671
8687	160.0	-331.6	2	69219.1	59223
8788	174.0	-317.6	2	69219.1	80844
8889	689.0	197.4	6	69219.1	105846

FA=480

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1477.0	425.0	13	217871	273337
8384	1056.0	4.0	12	217871	171197
8485	916.0	-136.0	10	217871	160603
8586	1158.0	106.0	14	217871	198017
8687	797.0	-255.0	14	217871	128219
8788	859.0	-193.0	11	217871	142989
8889	1101.0	49.0	12	217871	186482

FA=490

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	182.0	-397.4	4	67971.4	23064
8384	769.0	189.6	8	67971.4	71488
8485	653.0	73.6	7	67971.4	85463
8586	1001.0	421.6	8	67971.4	190909
8687	437.0	-142.4	5	67971.4	65000
8788	348.0	-231.4	4	67971.4	83337
8889	666.0	86.6	7	67971.4	114374

Summary of Transient Variables
by FA and year

FA=530

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1069.7	106.1	11	208432	148220
8384	1235.1	271.6	9	208432	284039
8485	796.0	-167.5	7	208432	224729
8586	1069.0	105.5	9	208432	217395
8687	505.0	-458.5	6	208432	109703
8788	935.0	-28.5	8	208432	208838
8889	1135.0	171.5	9	208432	301506

FA=540

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	469.0	-257.6	4	186172	145800
8384	1299.7	573.1	11	186172	208756
8485	717.0	-9.6	6	186172	151118
8586	961.5	234.9	10	186172	151893
8687	345.0	-381.6	5	186172	63166
8788	645.0	-81.6	7	186172	133429
8889	649.0	-77.6	6	186172	182537

FA=550

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	670.0	-40.0	11	139912	114391
8384	831.0	121.0	11	139912	158484
8485	691.0	-19.0	9	139912	156735
8586	784.1	74.1	10	139912	159965
8687	599.0	-111.0	10	139912	84173
8788	606.0	-104.0	6	139912	149746
8889	789.0	79.0	9	139912	205676

FA=560

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	235.0	-226.4	3	142128	89408
8384	621.0	159.6	8	142128	103059
8485	961.0	499.6	8	142128	128602
8586	522.0	60.6	6	142128	77850
8687	227.0	-234.4	4	142128	54200
8788	194.0	-267.4	3	142128	61034
8889	470.0	8.6	6	142128	91236

Summary of Transient Variables
by FA and year

FA=570

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	342.0	-209.4	4	169637	85577
8384	913.1	361.6	9	169637	150581
8485	525.0	-26.4	7	169637	95998
8586	788.0	236.6	6	169637	124392
8687	376.0	-175.4	6	169637	60719
8788	301.0	-250.4	4	169637	87534
8889	615.0	63.6	6	169637	130035

FA=580

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1529.2	280.7	15	195935	394878
8384	1749.0	500.5	15	195935	395038
8485	1167.0	-81.5	12	195935	304580
8586	1238.4	-10.1	11	195935	333390
8687	759.0	-489.5	11	195935	140576
8788	1139.9	-108.6	13	195935	219989
8889	1157.0	-91.5	13	195935	305731

FA=590

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1303.0	198.0	17	154463	228182
8384	1165.0	60.0	14	154463	246197
8485	1097.0	-8.0	13	154463	229792
8586	1349.0	244.0	14	154463	251196
8687	706.0	-399.0	11	154463	124922
8788	1046.0	-59.0	13	154463	208199
8889	1069.0	-36.0	12	154463	230922

FA=640

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1970.9	466.9	19	172071	328064
8384	1734.0	230.0	19	172071	215862
8485	1583.0	79.0	16	172071	239602
8586	1809.7	305.7	16	172071	241311
8687	1338.0	-166.0	19	172071	118566
8788	1028.0	-476.0	11	172071	200677
8889	1064.3	-439.6	8	172071	318668

Summary of Transient Variables by FA and year

FA=650

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1400.0	97.0	16	176250	159904
8384	1368.7	65.8	12	176250	180532
8485	1143.1	-159.8	8	176250	184479
8586	1507.9	205.0	12	176250	184766
8687	909.0	-393.9	12	176250	89032
8788	823.0	-479.9	9	176250	136836
8889	1968.7	665.8	14	176250	236352

FA=660

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	1340.0	212.7	18	151834	155195
8384	1708.0	580.7	20	151834	199622
8485	1029.0	-98.3	16	151834	160708
8586	1020.0	-107.3	14	151834	174163
8687	643.0	-484.3	14	151834	128831
8788	1074.0	-53.3	16	151834	188303
8889	1077.0	-50.3	12	151834	248348

FA=670

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	740.8	253.2	10	85729	75133
8384	375.4	-112.1	7	85729	63417
8485	747.8	260.2	9	85729	76890
8586	540.0	52.4	10	85729	55648
8687	212.0	-275.6	5	85729	27104
8788	203.0	-284.6	5	85729	33575
8889	594.0	106.4	10	85729	78895

FA=680

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	879.9	159.1	8	75019.2	163602
8384	666.0	-54.8	9	75019.2	114242
8485	1065.9	345.1	13	75019.2	113008
8586	634.0	-86.8	9	75019.2	107351
8687	209.0	-511.8	2	75019.2	64719
8788	441.0	-279.8	9	75019.2	68016
8889	1149.7	428.9	12	75019.2	153589

Summary of Transient Variables
by FA and year

FA=690

YEAR	TSH	d_TSH	N_ST	PREDICTED COST	ACTUAL COST
8283	2023.3	430.1	18	231240	170924
8384	1562.8	-30.4	11	231240	234908
8485	2115.3	522.1	11	231240	282589
8586	1070.7	-522.4	5	231240	238395
8687	881.0	-712.2	10	231240	125678
8788	1271.0	-322.2	12	231240	172649
8889	2228.1	634.9	12	231240	298614

APPENDIX D

LABOR, EQUIPMENT, MATERIAL AND TOTAL COST BY FA AND YEAR

Labor, Equipment, Material and Total Cost by FA and year

FA=120

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	38722	45282	23079	107083
8384	37947	29997	29890	97834
8485	64418	49608	44041	158067
8586	55157	48497	41789	145443
8687	56888	50546	43960	151394
8788	29578	28386	47028	104992
8889	55048	44080	49816	148944

FA=130

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	80332	191562	42385	314279
8384	91215	79817	71410	242442
8485	131136	104946	58236	294318
8586	95625	99930	77285	272840
8687	85674	92225	75564	253463
8788	80035	92385	75089	247509
8889	140266	140312	128304	408882

FA=140

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	79835	146960	31719	258514
8384	95930	111326	48500	255756
8485	114793	125047	43064	282904
8586	93159	106763	67583	267505
8687	86733	94171	92440	273344
8788	89667	115936	122383	327986
8889	153731	150923	127036	431690

FA=150

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	57403	91872	64437	213712
8384	76514	90532	100991	268037
8485	112904	144064	91819	348787
8586	107055	149905	108937	365897
8687	90155	132834	108129	331118
8788	81430	125567	122983	329980
8889	156534	195083	169967	521584

Labor, Equipment, Material and Total Cost
by FA and year

FA=160

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	66105	58862	38456	163423
8384	75133	50523	71155	196811
8485	111031	85419	64754	261204
8586	119292	103894	92091	315277
8687	84183	77674	81132	242989
8788	91589	80085	92039	263713
8889	124941	108254	145762	378957

FA=170

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	76450	90816	60368	227634
8384	108675	89552	100812	299039
8485	179176	150336	101577	431089
8586	157528	136439	124201	418168
8687	107790	93813	101722	303325
8788	120692	114021	155301	390014
8889	184880	155534	195045	535459

FA=220

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	46083	129716	21606	197405
8384	58487	51544	28475	138506
8485	85266	74131	37392	196789
8586	71719	67186	36892	175797
8687	62075	57103	36684	155862
8788	57649	54421	46920	158990
8889	110392	90073	63318	263783

FA=240

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	44240	42123	25225	111588
8384	61739	48243	33529	143511
8485	99071	73182	43014	215267
8586	78132	64418	45880	188430
8687	60366	49028	56255	165649
8788	61955	58217	56680	176852
8889	112021	83128	61252	256401

Labor, Equipment, Material and Total Cost
by FA and year

FA=250

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	35600	30775	10453	76828
8384	51713	38289	17628	107630
8485	80077	62977	14606	157660
8586	61941	52782	24364	139087
8687	42638	36518	19864	99020
8788	50285	44451	21735	116471
8889	85896	78638	44832	209366

FA=260

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	78775	71097	27682	177554
8384	91720	76570	40548	208838
8485	112632	81984	47755	242371
8586	101465	87236	55247	243948
8687	106658	93523	66583	266764
8788	136000	113904	71685	321589
8889	166406	130028	76588	373022

FA=270

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	39280	37886	15072	92238
8384	62199	50458	34602	147259
8485	76901	56825	33354	167080
8586	65827	52890	38027	156744
8687	55213	43322	33994	132529
8788	58188	51308	40701	150197
8889	81520	65833	44190	191543

FA=290

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	41555	32742	6439	80736
8384	83387	57440	10342	151169
8485	82679	52820	14233	149732
8586	77612	57617	18350	153579
8687	61160	43360	13651	118171
8788	69653	53935	18200	141788
8889	102338	83384	29444	215166

Labor, Equipment, Material and Total Cost
by FA and year

FA=320

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	68528	68406	17918	154852
8384	83571	72703	33543	189817
8485	90022	73647	29049	192718
8586	92654	86277	35573	214504
8687	63726	64817	28238	156781
8788	73343	80273	32594	186210
8889	115094	117855	41759	274708

FA=330

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	29283	29774	7732	66789
8384	48401	37529	17532	103462
8485	41572	30098	18856	90526
8586	55139	41143	21925	118207
8687	45831	38860	14058	98749
8788	40585	45568	21712	107865
8889	71725	61678	36304	169707

FA=340

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	31945	37944	12302	82191
8384	73932	57630	57004	188566
8485	55485	41974	44346	141805
8586	66404	56844	61124	184372
8687	31345	30747	11136	73228
8788	41715	39903	33286	114904
8889	87189	90001	72624	249814

FA=350

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	55411	56670	22966	135047
8384	92782	85259	49731	227772
8485	75149	59029	35640	169818
8586	81596	71849	53142	206587
8687	46432	43881	18457	108770
8788	47608	51624	20505	119737
8889	82844	88104	32470	203418

Labor, Equipment, Material and Total Cost by FA and year

FA=370

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	43953	54129	14750	112832
8384	79167	76688	56465	212320
8485	54823	42100	36347	133270
8586	65406	65382	54920	185708
8687	41338	45172	22256	108766
8788	38623	41243	28828	108694
8889	67995	60620	59364	187979

FA=380

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	62856	79198	20824	162878
8384	79107	73504	42491	195102
8485	88797	74653	42089	205539
8586	88200	82045	34492	204737
8687	47872	68431	27148	143451
8788	57973	83801	28967	170741
8889	92227	117647	40930	250804

FA=390

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	58619	103099	4757	166475
8384	56485	63883	6922	127290
8485	81658	79763	11548	172969
8586	76654	89971	10680	177305
8687	49344	47456	9187	105987
8788	69844	72825	12166	154835
8889	105443	108621	22110	236174

FA=430

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	62198	87067	32517	181782
8384	123861	111438	80140	315439
8485	88063	72112	60076	220251
8586	83934	76914	69818	230666
8687	37666	38694	37198	113558
8788	64386	64586	63390	192362
8889	100532	87691	72945	261168

Labor, Equipment, Material and Total Cost
by FA and year

FA=450

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	57361	66862	9918	134141
8384	95464	78227	12695	186386
8485	86058	62963	7126	156147
8586	62442	51460	9843	123745
8687	33583	28609	13832	76024
8788	39946	35375	23890	99211
8889	105069	86015	37536	228620

FA=460

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	15754	21630	9125	46509
8384	47797	42256	44797	134850
8485	30172	24703	35119	89994
8586	42049	39676	45946	127671
8687	20395	22459	16369	59223
8788	26696	29419	24729	80844
8889	37283	30900	37663	105846

FA=480

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	105943	157140	10254	273337
8384	87225	75758	8214	171197
8485	89614	65585	5404	160603
8586	95544	93123	9350	198017
8687	69234	51064	7921	128219
8788	73007	58688	11294	142989
8889	94622	75378	16482	186482

FA=490

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	8256	10614	4194	23064
8384	30187	24134	17167	71488
8485	38703	28616	18144	85463
8586	69655	64235	57019	190909
8687	25334	24597	15069	65000
8788	30598	31394	21345	83337
8889	40474	37509	36391	114374

Labor, Equipment, Material and Total Cost
by FA and year

FA=530

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	49306	64222	34692	148220
8384	100065	98268	85706	284039
8485	69868	74115	80746	224729
8586	66995	68714	81686	217395
8687	38286	35848	35569	109703
8788	74781	74318	59739	208838
8889	109957	95734	95815	301506

FA=540

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	37587	53961	54252	145800
8384	62605	59690	86461	208756
8485	46901	45905	58312	151118
8586	48631	48676	54586	151893
8687	22015	22117	19034	63166
8788	39508	43292	50629	133429
8889	59811	62225	60501	182537

FA=550

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	38038	43665	32688	114391
8384	48233	42511	67740	158484
8485	46074	43556	67105	156735
8586	45111	47549	67305	159965
8687	26968	25321	31884	84173
8788	46399	49210	54137	149746
8889	66556	62656	76464	205676

FA=560

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	23180	46682	19546	89408
8384	40446	32984	29629	103059
8485	53425	48033	27144	128602
8586	33244	31386	13220	77850
8687	18681	18380	17139	54200
8788	19323	18398	23313	61034
8889	41517	32553	17166	91236

Labor, Equipment, Material and Total Cost
by FA and year

FA=570

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	26877	32970	25730	85577
8384	53730	58975	37876	150581
8485	37142	32899	25957	95998
8586	43355	41141	39896	124392
8687	23543	20752	16424	60719
8788	34395	27699	25440	87534
8889	51441	46477	32117	130035

FA=580

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	89972	232047	72859	394878
8384	108264	130356	156418	395038
8485	91684	91607	121289	304580
8586	88670	111726	132994	333390
8687	42896	50344	47336	140576
8788	68759	89697	61533	219989
8889	91706	126687	87338	305731

FA=590

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	86613	93211	48358	228182
8384	90745	82150	73302	246197
8485	86227	74822	68743	229792
8586	84940	89148	77108	251196
8687	44781	42544	37597	124922
8788	74871	74742	58586	208199
8889	93706	86472	50744	230922

FA=640

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	117814	208295	1955	328064
8384	110311	103892	1659	215862
8485	123039	114949	1614	239602
8586	124055	114387	2869	241311
8687	59525	54188	4853	118566
8788	93320	98814	8543	200677
8889	143436	159332	15900	318668

Labor, Equipment, Material and Total Cost by FA and year

FA=650

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	67569	85671	6664	159904
8384	93479	76551	10502	180532
8485	99513	79246	5720	184479
8586	95173	80725	8868	184766
8687	46211	38229	4592	89032
8788	66166	60943	9727	136836
8889	117545	107633	11174	236352

FA=660

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	61769	76156	17270	155195
8384	83564	90227	25831	199622
8485	76329	62152	22227	160708
8586	75555	75208	23400	174163
8687	57804	53292	17735	128831
8788	80538	83058	24707	188303
8889	114927	107451	25970	248348

FA=670

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	34780	38926	1427	75133
8384	34742	27513	1162	63417
8485	41818	32877	2195	76890
8586	29452	24054	2142	55648
8687	14792	10767	1545	27104
8788	18060	13319	2196	33575
8889	41403	35168	2324	78895

FA=680

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	74331	84741	4530	163602
8384	63798	46879	3565	114242
8485	64669	44855	3484	113008
8586	57267	45850	4234	107351
8687	36186	25565	2968	64719
8788	34108	30012	3896	68016
8889	76838	65543	11208	153589

Labor, Equipment, Material and Total Cost
by FA and year

FA=690

YEAR	LABOR COST	EQUIPMENT COST	MATERIAL COST	TOTAL COST
8283	72815	79672	18437	170924
8384	112911	91408	30589	234908
8485	139355	120774	22460	282589
8586	113295	96317	28783	238395
8687	63330	50217	12131	125678
8788	78872	69436	24341	172649
8889	146737	121370	30507	298614

APPENDIX E

"BEST-FIT" MODELS - COMPUTER OUTPUT

Table E-1

Analysis of Variance

DEP VARIABLE: TAC
ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	5	139073911388	27814782278	16.031	0.0001
ERROR	31	53786548257	1735049944		
C TOTAL	36	192860459645			

ROOT MSE	41653.93	R-SQUARE	0.7211
DEP MEAN	183092.3	ADJ R-SQ	0.6761
C.V.	22.75024		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-104424.75	47192.56930	-2.213	0.0344
LSASH	1	359.16969	62.00858476	5.792	0.0001
ELEVTLM	1	-0.03117893	0.01240270	-2.514	0.0173
CURVTLM	1	0.16115399	0.04385107	3.675	0.0009
SF	1	91273.35657	14799.24367	6.167	0.0001
WF	1	-18016.65832	8762.96626	-2.056	0.0483

Table E-2

Confidence Limits and Residuals

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	LOWER95% PREDICT	UPPER95% PREDICT	RESIDUAL
1	120	130537	168157	16320.1	134872	201442	76915.8	259398	-37620.1
2	130	290533	286481	16033.2	253781	319181	195452	377510	4052.3
3	140	299671	265450	16688.0	231415	299486	173933	356968	34220.8
4	150	339874	299346	16603.3	265484	333209	207893	390800	40527.2
5	160	260339	230355	12316.9	205234	255475	141765	318944	29984.4
6	170	372104	341747	20774.0	299379	384116	246815	436679	30356.8
7	220	183876	204939	16806.1	170663	239216	113332	296547	-21063.4
8	240	179671	194311	18397.4	156789	231832	101441	287181	-14639.8
9	250	129437	190690	15233.7	159621	221759	100233	281146	-61252.2
10	260	262012	258142	15693.0	226136	290148	167359	348924	3870.5
11	270	148227	188912	16378.6	155508	222316	97627.8	280197	-40685.2
12	290	144334	159675	14358.5	130391	188959	69816.2	249534	-15340.5
13	320	195656	246944	15039.1	216271	277616	156623	337264	-51288.0
14	330	107901	131719	17541.6	95943.3	167496	39540.4	223898	-23818.7
15	340	147840	131342	18475.4	93661.5	169023	38407.4	224277	16497.9
16	350	167307	154912	21214.3	111645	198178	59575.4	250248	12395.2
17	370	149938	136937	18215.6	99786.1	174087	44215.6	229658	13001.7
18	380	190465	149950	12886.2	123669	176231	61024.5	238876	40514.5
19	390	163005	165629	18429.0	128043	203215	72732.4	258525	-2623.8
20	430	216461	231491	25906.3	178655	284327	131447	331534	-15029.8
21	450	143468	193402	14518.2	163792	223012	103437	283367	-49934.3
22	460	92133.9	69219.1	19662.6	29117.2	109321	-24723.4	163162	22914.8
23	480	180121	217871	17475.0	182231	253511	125745	309997	-37750.6
24	490	90519.3	67971.4	18463.8	30314.6	105628	-24953.7	160897	22547.9
25	530	213490	208432	12079.1	183796	233067	119978	296885	5058.5
26	540	148100	186172	12949.8	159761	212583	97207.9	275136	-38072.0
27	550	147024	139912	13086.2	113223	166601	50864.9	228959	7112.5
28	560	86484.1	142128	11683.8	118299	165957	53895.8	230360	-55643.6
29	570	104977	169637	10169.3	148897	190378	82189.1	257086	-64660.8
30	580	299169	195935	14654.0	166048	225822	105878	285992	103234
31	590	217059	154463	10830.3	132375	176552	66685.4	242241	62595.4
32	640	237536	172071	14431.6	142638	201504	82163.3	261978	65464.9
33	650	167414	176250	12081.3	151611	200890	87796.1	264705	-8835.9
34	660	179310	151834	26030.2	98744.9	204922	51656.5	252011	27476.5
35	670	58666.0	85729.0	18793.3	47400.2	124058	-7470.5	178928	-27063.0
36	680	112075	75019.2	17743.9	38830.4	111208	-17320.8	167359	37056.1
37	690	217680	231240	18481.6	193546	268933	138300	324180	-13560.1

Table E-3

Students Residual and Cook's D

OBS	ID	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	120	38323.7	-0.9816	*	0.029
2	130	38444.6	0.1054		0.000
3	140	38164.9	0.8967	*	0.026
4	150	38201.8	1.0609	**	0.035
5	160	39791.3	0.7535	*	0.009
6	170	36103.9	0.8408	*	0.039
7	220	38113.0	-0.5527	*	0.010
8	240	37370.9	-0.3917		0.006
9	250	38768.4	-1.5800	***	0.064
10	260	38584.7	0.1003		0.000
11	270	38298.7	-1.0623	**	0.034
12	290	39100.9	-0.3923		0.003
13	320	38844.2	-1.3203	**	0.044
14	330	37780.2	-0.6305	*	0.014
15	340	37332.4	0.4419		0.008
16	350	35846.9	0.3458		0.007
17	370	37459.9	0.3471		0.005
18	380	39610.6	1.0228	**	0.018
19	390	37355.3	-0.0702		0.000
20	430	32617.7	-0.4608		0.022
21	450	39041.9	-1.2790	**	0.038
22	460	36721.0	0.6240	*	0.019
23	480	37811.0	-0.9984	*	0.035
24	490	37338.2	0.6039	*	0.015
25	530	39864.1	0.1269		0.000
26	540	39589.8	-0.9617	*	0.016
27	550	39544.9	0.1799		0.001
28	560	39981.7	-1.3917	**	0.028
29	570	40393.5	-1.6008	***	0.027
30	580	38991.1	2.6476	*****	0.165
31	590	40221.3	1.5563	***	0.029
32	640	39074.0	1.6754	***	0.064
33	650	39863.4	-0.2217		0.001
34	660	32518.9	0.8449	*	0.076
35	670	37173.4	-0.7280	*	0.023
36	680	37685.6	0.9833	*	0.036
37	690	37329.4	-0.3633		0.005

SUM OF RESIDUALS -2.62844E-10
SUM OF SQUARED RESIDUALS 53786548257
PREDICTED RESID SS (PRESS) 71959605245

Chart E-1

Residual Plot

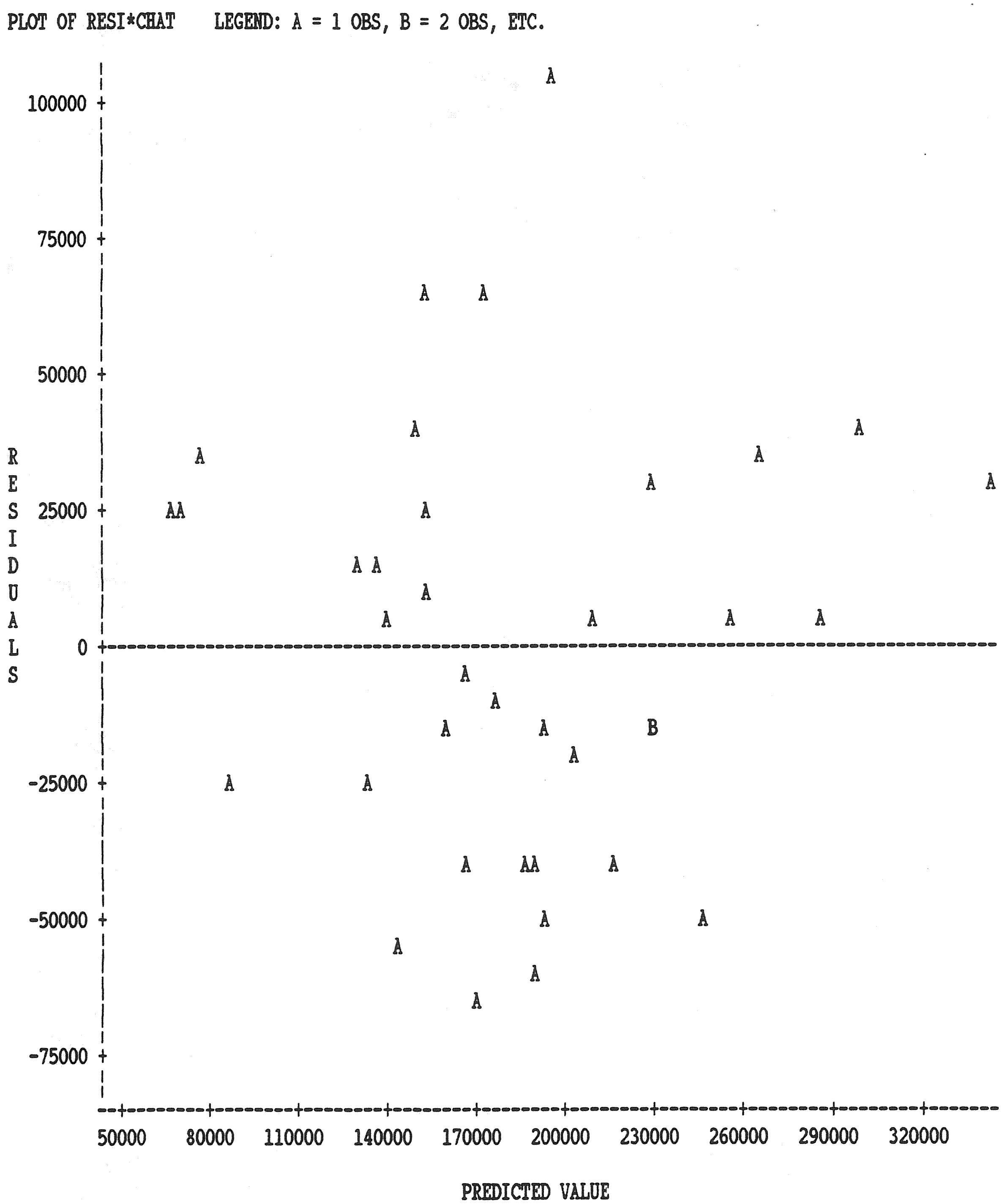

Table E-4

Transient Cost Model

DIST=1

DEP VARIABLE: DELC

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	826157671511	413078835755	71.047	0.0007
ERROR	4	23256559169	5814139792		
C TOTAL	6	849414230680			

ROOT MSE	76250.51	R-SQUARE	0.9726
DEP MEAN	101521.5	ADJ R-SQ	0.9589
C.V.	75.10771		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-1998415.36	496649.25	-4.024	0.0158
DELST	1	103.54888	14.23601344	7.274	0.0019
SII	1	58806.60728	13884.72306	4.235	0.0133

Predicetd Costs

YEAR	TOTAL DISTRICT COST	PREDICTED AVERAGE DISTRICT COST	PREDICTED TRANSIENT DISTRICT COST	RELATIVE PERCENTAGE ERROR
8283	1284645	1591536	1314179	-2.3
8384	1359919	1591536	1347796	0.9
8485	1776369	1591536	1769073	0.4
8586	1785130	1591536	1774549	0.6
8687	1555633	1591536	1469275	5.6
8788	1664194	1591536	1781244	-7.0
8889	2425516	1591536	2395289	1.2

Table E-5

Transient Cost Model

DIST=2

DEP VARIABLE: DELC

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	345479548126	172739774063	109.495	0.0003
ERROR	4	6310440528	1577610132		
C TOTAL	6	351789988654			

ROOT MSE	39719.14	R-SQUARE	0.9821
DEP MEAN	-149111	ADJ R-SQ	0.9731
C.V.	-26.6374		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR HO: PARAMETER=0	PROB > |T|
INTERCEP	1	-2101996.72	231269.30	-9.089	0.0008
DELST	1	80.10650389	8.88207377	9.019	0.0008
SII	1	54688.59743	6462.80315	8.462	0.0011

Predicetd Costs

YEAR	TOTAL DISTRICT COST	PREDICTED AVERAGE DISTRICT COST	PREDICTED TRANSIENT DISTRICT COST	RELATIVE PERCENTAGE ERROR
8283	736349	1196669	699830	5.0
8384	896913	1196669	931216	-3.8
8485	1128899	1196669	1136687	-0.7
8586	1057585	1196669	1060966	-0.3
8687	937995	1196669	918194	2.1
8788	1065887	1196669	1111790	-4.3
8889	1509281	1196669	1474226	2.3

Table E-6

Transient Cost Model

DIST=3

DEP VARIABLE: DELC

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	401810068957	200905034479	23.011	0.0064
ERROR	4	34923521726	8730880432		
C TOTAL	6	436733590684			

ROOT MSE	93439.18	R-SQUARE	0.9200
DEP MEAN	4678.829	ADJ R-SQ	0.8801
C.V.	1997.063		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-1960038.66	530670.16	-3.694	0.0210
DELST	1	142.68567	22.52646609	6.334	0.0032
SII	1	55019.92453	14827.93436	3.711	0.0206

Predicetd Costs

YEAR	TOTAL DISTRICT COST	PREDICTED AVERAGE DISTRICT COST	PREDICTED TRANSIENT DISTRICT COST	RELATIVE PERCENTAGE ERROR
8283	881064	1117433	910340	-3.3
8384	1244329	1117433	1307911	-5.1
8485	1106645	1117433	1067703	3.5
8586	1291420	1117433	1153800	10.7
8687	795732	1117433	784684	1.4
8788	962986	1117433	1060146	-10.1
8889	1572604	1117433	1570196	0.2

Table E-7

Transient Cost Model

DIST=4

DEP VARIABLE: DELC

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	156467115952	78233557976	16.823	0.0113
ERROR	4	18601713653	4650428413		
C TOTAL	6	175068829605			

ROOT MSE	68194.05	R-SQUARE	0.8937
DEP MEAN	-57252	ADJ R-SQ	0.8406
C.V.	-119.112		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-889279.39	413061.68	-2.153	0.0977
DELST	1	123.52476	21.32987949	5.791	0.0044
SII	1	23300.08528	8259.51306	2.821	0.0478

Predicetd Costs

YEAR	TOTAL DISTRICT COST	PREDICTED AVERAGE DISTRICT COST	PREDICTED TRANSIENT DISTRICT COST	RELATIVE PERCENTAGE ERROR
8283	658833	779954	642056	2.5
8384	879360	779954	949430	-8.0
8485	712458	779954	669133	6.1
8586	871008	779954	798316	8.3
8687	442024	779954	519831	-17.6
8788	598743	779954	584816	2.3
8889	896490	779954	895333	0.1

Table E-8

Transient Cost Model

DIST=5

DEP VARIABLE: DELC

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	458009342084	458009342084	29.798	0.0028
ERROR	5	76852518900	15370503780		
C TOTAL	6	534861860983			

ROOT MSE	123977.8	R-SQUARE	0.8563
DEP MEAN	19623.79	ADJ R-SQ	0.8276
C.V.	631.773		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	19623.79488	46859.21739	0.419	0.6928
DELST	1	203.80901	37.33621285	5.459	0.0028

Predicetd Costs

YEAR	TOTAL DISTRICT COST	PREDICTED AVERAGE DISTRICT COST	PREDICTED TRANSIENT DISTRICT COST	RELATIVE PERCENTAGE ERROR
8283	1206456	1196678	1186008	1.7
8384	1546154	1196678	1633559	-5.7
8485	1291554	1196678	1254509	2.9
8586	1316081	1196678	1409017	-7.1
8687	637459	1196678	757829	-18.9
8788	1068769	1196678	1032947	3.4
8889	1447643	1196678	1240247	14.3

Table E-9

Transient Cost Model

DIST=6

DEP VARIABLE: DELC

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	342527825488	171263912744	74.313	0.0007
ERROR	4	9218475082	2304618771		
C TOTAL	6	351746300570			

ROOT MSE	48006.45	R-SQUARE	0.9738
DEP MEAN	80538.46	ADJ R-SQ	0.9607
C.V.	59.60686		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-1467398.73	298096.20	-4.923	0.0079
DELST	1	164.27308	13.47866936	12.188	0.0003
SII	1	43348.41394	8332.40365	5.202	0.0065

Predicetd Costs

YEAR	TOTAL DISTRICT COST	PREDICTED AVERAGE DISTRICT COST	PREDICTED TRANSIENT DISTRICT COST	RELATIVE PERCENTAGE ERROR
8283	1052822	892143	1080226	-2.6
8384	1008583	892143	978634	3.0
8485	1057276	892143	1075665	-1.7
8586	1001634	892143	947481	5.4
8687	553930	892143	607628	-9.7
8788	800056	892143	766887	4.1
8889	1334466	892143	1352247	-1.3

APPENDIX F

COST MODEL - SOURCE CODE LISTING

COST MODEL - SOURCE CODE LISTING

File Name: COST.BAS
Compiler : MS QuickBASIC (4.0 or above)

```
DECLARE SUB printout ()
DECLARE SUB wcostcal (ndist!, dcost!, ndeltsh, nsii, wcost!)
DECLARE SUB outscr3 (ndist!, yrin!, wcost!)
DECLARE SUB scrtime (ndist!, t() AS ANY, ndeltsh, nsii, yrin)
DECLARE SUB outscr1 (nfa!, acost!)
DECLARE SUB outscr2 (ndist!, dcost!, dcfa() AS DOUBLE, s() AS ANY, mark2()
AS INTEGER, jj!, season$)
DECLARE SUB avgcost (nls!, ntlm!, nelev!, nash!, ncurves!, nsf!, nwf!,
acost!)
DECLARE SUB lscal (nls!, ntlm!)
DECLARE SUB scr4 (mark!, ndist!, nfa!, t() AS ANY, s() AS ANY, nls, ntlm,
nelev, nash, ncurves, nsf, nwf)
DECLARE SUB info (file$, t() AS ANY, s() AS ANY)
DECLARE SUB errscr ()
DECLARE SUB scr3 (anal$, fa, dist)
DECLARE SUB scr2 (anal$)
DECLARE SUB scr1 ()


TYPE steady
       obs AS INTEGER
       fa AS INTEGER
       ls AS SINGLE
       ash AS SINGLE
       elev AS SINGLE
       tlm AS SINGLE
       curves AS INTEGER
       sf AS SINGLE
       wf AS SINGLE
END TYPE
TYPE trans
       obst AS INTEGER
       dist AS INTEGER
       yr12 AS INTEGER
       yash AS SINGLE
       deltsh AS SINGLE
       sii AS DOUBLE
       tsh AS SINGLE
END TYPE

DIM t(1 TO 42) AS trans, s(1 TO 37)  AS steady
DIM mark2(1 TO 10)  AS INTEGER
DIM dcfa(1 TO 10) AS DOUBLE

file$ = "A:"                    ' Data file directory
```

```
acost = 0: dcost = 0


CALL scrl
CALL scr2(anal$)
CALL scr3(anal$, nfa, ndist)

CALL info(file$, t(), s())
CLS

IF nfa <> 0 THEN
            FOR ii = 1 TO 37
                IF s(ii).fa = nfa THEN markl = ii
            NEXT ii
            IF markl = 0 THEN CALL errscr
            CALL scr4(markl, ndist, nfa, t(), s(), nls, ntlm, nelev, nash,
ncurves, nsf, nwf)
            CALL avgcost(nls, ntlm, nelev, nash, ncurves, nsf, nwf, acost)
            CALL outscrl(nfa, acost)
END IF

IF nfa = 0 THEN
               jj = 0
               FOR ii = 1 TO 37
                   IF (INT(s(ii).fa / 100)) = ndist THEN
                                                         jj = jj + 1
                                                         mark2(jj) = ii
                                                        END IF
               NEXT ii
               IF mark2(1) = 0 THEN CALL errscr
               FOR kk = 1 TO jj
                   zz = s(mark2(kk)).fa
                   uu = mark2(kk)
                   CALL scr4(uu, ndist, zz, t(), s(), nls, ntlm, nelev,
nash, ncurves, nsf, nwf)
                   CALL avgcost(nls, ntlm, nelev, nash, ncurves, nsf, nwf,
acost)
                   dcfa(kk) = acost
                   dcost = dcost + acost
               NEXT kk
               CALL outscr2(ndist, dcost, dcfa(), s(), mark2(), jj, season$)
               CALL scrtime(ndist, t(), ndeltsh, nsii, yrin)
               CALL wcostcal(ndist, dcost, ndeltsh, nsii, wcost)
               CALL outscr3(ndist, yrin, wcost)


END IF
END
```

```
SUB avgcost (nls, ntlm, nelev, nash, ncurves, nsf, nwf, acost)
acost = -104424.75# + 359.16969# * nash * nls - .03117893# * ntlm * nelev
+ .16115399# * ncurves * ntlm + 91273.35657# * nsf - 18016.65832# * nwf
END SUB

SUB errscr
CLS
LOCATE 10, 35, 0
PRINT "E R R O R"
LOCATE 14, 32, 0
PRINT " Check your input"
LOCATE 16, 19, 0
PRINT "FA / DISTRICT requested not found on data files"

END SUB




SUB info (file$, t() AS trans, s() AS steady) STATIC

dirchange:  file1$ = file$ + "\steady.dat"
            file2$ = file$ + "\Trans.dat"

OPEN file1$ FOR INPUT AS #1

FOR ii = 1 TO 37
     INPUT #1, s(ii).obs, s(ii).fa, s(ii).ls, s(ii).ash, s(ii).elev,
s(ii).tlm, s(ii).curves, s(ii).sf, s(ii).wf
     NEXT ii
CLOSE #1

OPEN file2$ FOR INPUT AS #2
FOR jj = 1 TO 42
     INPUT #2, t(jj).obst, t(jj).dist, t(jj).yr12, t(jj).yash,
t(jj).deltsh, t(jj).sii, t(jj).tsh
NEXT jj
CLOSE #2

END SUB




SUB lscal (nls, ntlm)
CLS
LOCATE 3, 20, 0
PRINT "Enter lane-miles under each level of service :"
LOCATE 6, 25, 0
INPUT ; "Level of service 1    ", ls1
LOCATE 8, 25, 0
INPUT ; "Level of service 2    ", ls2
```

```
LOCATE 10, 25, 0
INPUT ; "Level of service 3    ", ls3
LOCATE 12, 25, 0
INPUT ; "Level of service 4    ", ls4
LOCATE 14, 25, 0
INPUT ; "Level of service 5    ", ls5
ntlm = ls1 + ls2 + ls3 + ls4 + ls5
nls = (5 * ls1 + 4 * ls2 + 3 * ls3 + 2 * ls4 + ls5) / ntlm

CALL printout

END SUB




SUB outscr1 (nfa, acost)
            CLS
            LOCATE 4, 37, 0
            PRINT "FA "; nfa
            LOCATE 7, 11, 0
            PRINT "  THE AVERAGE ANNUAL WINTER MAINTENANCE COST IS";
            PRINT USING "$$#######.##"; acost

            CALL printout

END SUB




SUB outscr2 (ndist, dcost, dcfa() AS DOUBLE, s() AS steady, mark2() AS
INTEGER, jj, season$)
            CLS
            LOCATE 2, 35, 0
            PRINT "DISTRICT "; ndist
            LOCATE 4, 6, 0
            PRINT "  THE AVERAGE ANNUAL WINTER MAINTENANCE COSTS FOR EACH
FA ARE :"
            FOR kk = 1 TO jj
                uu = mark2(kk)
                zz = s(uu).fa
                LOCATE (2 * kk + 4), 51, 0
                PRINT "FA "; zz
                LOCATE (2 * kk + 4), 63, 0
                PRINT USING "$$#######.##"; dcfa(kk)
             NEXT kk
             LOCATE (2 * jj + 7), 1, 0
             PRINT "The Average Annual Winter Maintenance Cost for District
"; ndist; " is";
             PRINT USING "$$########.##"; dcost
             LOCATE 24, 1, 0
```

```
            INPUT ; "Do you want to know the seasonal cost for any
particular winter ? (Y/N)", season$

            CALL printout

END SUB




SUB outscr3 (ndist, yrin, wcost)
CLS
LOCATE 8, 35, 0
PRINT "DISTRICT "; ndist
LOCATE 12, 8, 0
yr1 = INT(yrin / 100) + 1900: yr2 = yrin - (100 * INT(yrin / 100))
PRINT " Winter maintenance cost for "; yr1; "-"; yr2; " is ";
PRINT USING "$$#########.##"; wcost

CALL printout

END SUB




SUB printout
LOCATE 24, 1, 0
COLOR 0, 7, 0
PRINT "           If you want a printout press PRTSC now else press ENTER
          ";
LOCATE 24, 72, 0
INPUT ; ""; rama$
COLOR 7, 0, 0
END SUB




SUB scr1
CLS
LOCATE 8, 22, 0
PRINT "WINTER  MAINTENANCE  COST  ANALYSIS"
LOCATE 11, 39, 0
PRINT "By"
LOCATE 13, 30, 0
PRINT "Dr. Donald  F. Haber"
LOCATE 14, 40, 0
PRINT "&"
LOCATE 15, 33, 0
PRINT "Umesh  S. Limaye'"
LOCATE 24, 26, 0
```

```
PRINT "Press any key to continue..."
DO
LOOP WHILE INKEY$ = ""

END SUB




SUB scr2 (anal$) STATIC
CLS
LOCATE 6, 20, 0
PRINT " Do you want to analyze .."
LOCATE 8, 30, 0
PRINT "Average Cost for a foreman area (FA)    F"
LOCATE 10, 30, 0
PRINT "Seasonal cost for entire district       D"
LOCATE 12, 30, 0
PRINT "Both                                    B"
LOCATE 16, 25, 0
INPUT ; "Enter your selection and hit return    ", anal$

END SUB




SUB scr3 (anal$, nfa, ndist)
start:
CLS
IF anal$ = "f" OR anal$ = "F" THEN
        LOCATE 6, 12, 0
        PRINT "WARNING : FA number must be an integer ending with zero"
        LOCATE 12, 25, 0
        INPUT ; "Enter FA number : ", nfa
        IF ((INT(nfa / 10) * 10) <> nfa) OR nfa = 420 THEN GOTO start
        ndist = INT(nfa / 100)
END IF
IF anal$ = "D" OR anal$ = "d" OR anal$ = "b" OR anal$ = "B" THEN
        LOCATE 12, 25, 0
        INPUT ; "Enter District Number : ", ndist
        nfa = 0
END IF

        END SUB




SUB scr4 (ii, ndist, nfa, t() AS trans, s() AS steady, nls, ntlm, nelev,
nash, ncurves, nsf, nwf)
jb226 = 0
```

```
usl:
CLS
LOCATE 1, 35, 0
PRINT "DISTRICT "; ndist
LOCATE 3, 27, 0
PRINT "Current data for FA "; nfa
LOCATE 6, 11, 0
PRINT "Factor"
LOCATE 9, 1, 0
PRINT "Level of Service Factor (LS)"
LOCATE 11, 1, 0
PRINT "Total Lane Miles (TLM)"
LOCATE 13, 1, 0
PRINT "Average Elevation (ELEV)"
LOCATE 15, 1, 0
PRINT "Average Storm Hours (ASH)"
LOCATE 17, 1, 0
PRINT "Weighted Sum of Curves (CURVES)"
LOCATE 19, 1, 0
PRINT "Snow Factor (SF)"
LOCATE 21, 1, 0
PRINT "Wind Factor (WF)"
LOCATE 6, 36, 0
PRINT "Current Value"
LOCATE 9, 32, 0
PRINT USING "############.###"; s(ii).ls
LOCATE 11, 32, 0
PRINT USING "############.###"; s(ii).tlm
LOCATE 13, 32, 0
PRINT USING "############.###"; s(ii).elev
LOCATE 15, 32, 0
PRINT USING "############.###"; s(ii).ash
LOCATE 17, 32, 0
PRINT USING "################"; s(ii).curves
LOCATE 19, 32, 0
PRINT USING "############.###"; s(ii).sf
LOCATE 21, 32, 0
PRINT USING "############.###"; s(ii).wf
LOCATE 24, 21, 0
IF jb226 <> 226 THEN INPUT ; "Do you wish to change this ?          ( Y / N
)  ", jb$
IF jb226 = 226 THEN jb$ = "Y"
IF jb$ = "y" OR jb$ = "Y" THEN
         LOCATE 6, 51, 0
         PRINT "Change ?"
         LOCATE 7, 52, 0
         PRINT "Y or N"
         LOCATE 6, 65, 0
         PRINT "New  Value"
     IF jb226 <> 226 THEN
            LOCATE 9, 55, 0
            INPUT ; "", j1$
```

```
   IF j1$ = "y" OR j1$ = "Y" THEN
                                 CALL lscal(nls, ntlm)
                                 jb226 = 226
                                 GOTO usl
                                END IF
       LOCATE 11, 55, 0
     INPUT ; "", j2$
   IF j2$ = "y" OR j2$ = "Y" THEN
                                 CALL lscal(nls, ntlm)
                                 jb226 = 226
                                 GOTO usl
                                END IF
END IF
IF jb226 = 226 THEN
                 LOCATE 9, 63, 0
                 PRINT USING "######.###"; nls
                 LOCATE 11, 63, 0
                 PRINT USING "######.###"; ntlm
               END IF

   LOCATE 13, 55, 0
   INPUT ; "", j3$
   IF j3$ = "y" OR j3$ = "Y" THEN
                                LOCATE 13, 65, 0
                                INPUT ; "", nelev
   END IF
   LOCATE 15, 55, 0
   INPUT ; "", j4$
   IF j4$ = "y" OR j4$ = "Y" THEN
                                LOCATE 15, 65, 0
                                INPUT ; "", nash
   END IF
   LOCATE 17, 55, 0
   INPUT ; "", j5$
   IF j5$ = "y" OR j5$ = "Y" THEN
                                LOCATE 17, 65, 0
                                INPUT ; "", ncurves
   END IF
   LOCATE 19, 55, 0
   INPUT ; "", j6$
   IF j6$ = "y" OR j6$ = "Y" THEN
                                LOCATE 19, 65, 0
                                INPUT ; "", nsf
   END IF
   LOCATE 21, 55, 0
   INPUT ; "", j7$
   IF j7$ = "y" OR j7$ = "Y" THEN
                                LOCATE 21, 65, 0
                                INPUT ; "", nwf
   END IF
   IF j1$ = "n" OR j1$ = "N" THEN nls = s(ii).ls
   IF j2$ = "n" OR j2$ = "N" THEN ntlm = s(ii).tlm
```

```
         IF j3$ = "n" OR j3$ = "N" THEN nelev = s(ii).elev
         IF j4$ = "n" OR j4$ = "N" THEN nash = s(ii).ash
         IF j5$ = "n" OR j5$ = "N" THEN ncurves = s(ii).curves
         IF j6$ = "n" OR j6$ = "N" THEN nsf = s(ii).sf
         IF j7$ = "n" OR j7$ = "N" THEN nwf = s(ii).wf
END IF

         IF jb$ = "n" OR jb$ = "N" THEN
                              nls = s(ii).ls
                              ntlm = s(ii).tlm
                              nelev = s(ii).elev
                              nash = s(ii).ash
                              ncurves = s(ii).curves
                              nsf = s(ii).sf
                              nwf = s(ii).wf
                         END IF

CALL printout

END SUB




SUB scrtime (ndist, t() AS trans, ndeltsh, nsii, yrin)
yrcheck:
CLS
LOCATE 12, 17, 0
INPUT ; "Enter the winter year [ for example :1989-90 ] ", yearinput$
IF LEN(yearinput$) <> 7 THEN GOTO yrcheck
yrin = 100 * VAL(MID$(yearinput$, 3, 2)) + VAL(MID$(yearinput$, 6, 2))
IF yrin > 9899 OR yrin < 8182 THEN GOTO yrcheck
IF (INT(yrin / 100) - (yrin - 100 * INT(yrin / 100))) <> -1 THEN GOTO
yrcheck

CLS
LOCATE 2, 35, 0
PRINT "District "; ndist
LOCATE 4, 6, 0
PRINT "   Winter Year  "; "     "; "Total Storm Hours"; "     "; "Inflation
Index"
FOR ii = 1 TO 7
yr = t((ndist - 1) * 7 + ii).yr12
yr1 = INT(yr / 100) + 1900: yr2 = yr - (100 * INT(yr / 100))
LOCATE (ii * 2 + 4), 11, 0
PRINT yr1; "-"; yr2
LOCATE (ii * 2 + 4), 31, 0
PRINT USING "######.##"; t((ndist - 1) * 7 + ii).tsh
LOCATE (ii * 2 + 4), 50, 0
PRINT USING "###.###"; t((ndist - 1) * 7 + ii).sii
NEXT ii
```

```
LOCATE 20, 1, 0
PRINT "Average of total storm hours = "
LOCATE 20, 31, 0
xx = ((ndist - 1) * 7 + 2)
diff = (t(xx).tsh - t(xx).deltsh)
PRINT USING "######.##"; diff
IF (yrin < 8283) OR (yrin > 8889) THEN
        yr1 = INT(yrin / 100) + 1900: yr2 = yrin - (100 * INT(yrin / 100))
        COLOR 0, 7, 0
        LOCATE 22, 1, 0
        PRINT "Winter "; yr1; "-"; yr2
        COLOR 7, 0, 0
        LOCATE 23, 8, 0
        INPUT ; "Enter Total Storm Hours ", ntsh
        ndeltsh = ntsh - diff
        esii = 1.218297 * ((yrin - 8586) / 101) + 35.7092
        LOCATE 24, 8, 0
        PRINT "Extrapolated value of inflation index is ";
        PRINT USING "###.###"; esii;
        PRINT "   CHANGE (Y/N)";
        INPUT ; "", infl$
        IF infl$ = "Y" OR infl$ = "y" THEN
                        LOCATE 24, 8, 0
                        PRINT "
                     ";
                        LOCATE 24, 8, 0
                        INPUT ; "Enter new inflation index ", nsii
                     ELSE nsii = esii
                   END IF
ELSE
     FOR ll = 1 TO 42
     IF t(ll).dist = ndist AND t(ll).yrl2 = yrin THEN
                                             nsii = t(ll).sii
                                             ndeltsh = t(ll).deltsh
                                           END IF
     NEXT ll
     IF nsii = 0 THEN CALL errscr
        LOCATE 24, 26, 0
        PRINT "Press any key to continue..."
        DO
        LOOP WHILE INKEY$ = ""
END IF

 IF infl$ = "y" OR infl$ = "Y" THEN Extra$ = "" ELSE Extra$ = "Extrapolated"
 LOCATE 23, 42, 0
 outstring$ = Extra$ + " Inflation Index  "
 PRINT outstring$;
 PRINT USING "###.##"; nsii

CALL printout

END SUB
```

```
SUB wcostcal (ndist, dcost, ndeltsh, nsii, wcost)
DIM aa(1 TO 6) AS DOUBLE
DIM bb(1 TO 6) AS DOUBLE
DIM cc(1 TO 6) AS DOUBLE
        aa(1) = -1998415.36#: bb(1) = 103.54888#: cc(1) = 58806.60728#
        aa(2) = -2101996.72#: bb(2) = 80.10650389#: cc(2) = 54688.59743#
        aa(3) = -1960038.66#: bb(3) = 142.68567#: cc(3) = 55019.92453#
```

DOESN'T AGREE WITH TABLE 8-2

```
        aa(4) = -889279.39#: bb(4) = 123.54476#: cc(4) = 23300.08528#
```

DON'T AGREE WITH TABLE 8-2

```
        aa(5) = -813853.11#: bb(5) = 223.2347#: cc(5) = 23340.6771#
        aa(6) = -1467398.73#: bb(6) = 164.27308#: cc(6) = 43348.41394#

        wcost = dcost + aa(ndist) + bb(ndist) * ndeltsh + cc(ndist) * nsii

END SUB
```

APPENDIX G

SIMULATION - SOURCE CODE LISTING

SIMULATION - SOURCE CODE LISTING

File Name: SIMUL-B.BAS
Compiler : MS QuickBASIC (4.0 or above)

```
DECLARE SUB scrn2 (segcode$, bmp!, emp!, lanes!, wntadt!, work!, i$, lsc!,
lsp!, trip!)
DECLARE FUNCTION delay! (t!)
DECLARE SUB inflation (NoSimul, inflat!, yr$)
DECLARE SUB outscrn (lcost!, dcost!, segcode$, yr$, bmp!, emp!)
DECLARE SUB econ (uttu$, time1!, time2!, cost1!, cost2!)
DECLARE FUNCTION comfort! (t!)
DECLARE SUB indata (Va!(), rf!(), sigd!(), sigw!())
DECLARE SUB scrn1 ()
DIM Va(1 TO 6) AS SINGLE
DIM rf(1 TO 6) AS SINGLE
DIM sigd(1 TO 6) AS SINGLE
DIM sigw(1 TO 6) AS SINGLE

CONST pi = 3.141592654#
cost = 0: dcost = 0

CALL scrn1
CALL scrn2(segcode$, bmp, emp, lanes, wntadt, work, i$, lsc, lsp, trip)
CALL indata(Va(), rf(), sigd(), sigw())
IF i$ = "y" OR i$ = "Y" THEN jb = 0 ELSE jb = 1
jbc = (2 * lsc - 1) + jb
jbp = (2 * lsp - 1) + jb

IF wntadt > 4000 THEN NoSimul = wntadt / 2 ELSE NoSimul = 2000

CALL inflation(NoSimul, inflat, yr$)



RANDOMIZE TIMER

     FOR car = 1 TO NoSimul
       IF car = 1 THEN starttime = TIMER
         r1 = RND(1): r2 = RND(2)
         z1 = SQR(-2 * LOG(r1)) * COS(2 * pi * r2)
         z2 = SQR(-2 * LOG(r1)) * SIN(2 * pi * r2)
         v1c = Va(jbc) * rf(jbc) + sigw(jbc) * z1
         v1p = Va(jbp) * rf(jbp) + sigw(jbp) * z1
         v2c = Va(jbc) * rf(jbc) + sigw(jbc) * z2
         v2p = Va(jbp) * rf(jbp) + sigw(jbp) * z2
         time1 = trip * ((1 / v1c) - (1 / v1p)) * 60     'time in min.
         time2 = trip * ((1 / v2c) - (1 / v2p)) * 60     'time in min.
         ccost1 = comfort(time1)
         ccost2 = comfort(time2)
         dcost1 = delay(time1)
```

```
        dcost2 = delay(time2)
        ccost = (ccost1 + ccost2) * inflat + ccost
        dcost = (dcost1 + dcost2) * inflat + dcost
      IF car = 20 THEN
                    endtime = TIMER
                    SimulTime = (endtime - starttime) * NoSimul / (60 * 20)
                    St1 = INT(SimulTime)
                    st2 = INT((SimulTime - St1) * 60)
                    LOCATE 15, 20, 0
                    PRINT "Estimated Time for Simulation : "; St1; ":";
                    PRINT USING "##"; st2;
                    PRINT " min. "
                    COLOR 7, 0, 0
               END IF

    NEXT car


ccost = ccost / (2 * NoSimul)                           '     average costs
dcost = (dcost / (2 * NoSimul)) * (work / 100)          '   $ per car per day

ccost = ccost * wntadt                                  ' TOTAL COST
dcost = dcost * wntadt                                  ' $ per day


CALL outscrn(dcost, ccost, segcode$, yr$, bmp, emp)

END



FUNCTION comfort (t)
IF t < 7.66 THEN comfort = 0
IF t >= 7.66 AND t <= 15 THEN comfort = .085831062# * (t - 7.66)
IF t > 15 THEN comfort = .028 * (t - 15) + .63
END FUNCTION



FUNCTION delay (t)
IF t < 12 THEN delay = 0
IF t >= 12 THEN delay = .08533333# * (t - 12) + 1.024
END FUNCTION



SUB indata (Va(), rf(), sigd(), sigw())
        Va(1) = 50: rf(1) = .78: sigd(1) = 4.2: sigw(1) = 5.1
        Va(2) = 41: rf(2) = .79: sigd(2) = 5.8: sigw(2) = 4.1

        Va(3) = 50: rf(3) = .7:  sigd(3) = 4.2: sigw(3) = 5.1
        Va(4) = 41: rf(4) = .75: sigd(4) = 5.8: sigw(4) = 4.7
```

```
        Va(5) = 50: rf(5) = .58: sigd(5) = 4.2: sigw(5) = 4.2
        Va(6) = 41: rf(6) = .58: sigd(6) = 5.8: sigw(6) = 4!

END SUB


SUB inflation (NoSimul, inflat, yr$)
yrnot:
    CLS
    LOCATE 3, 23, 0
    INPUT ; "Input current Year (e.g. 1988-89)", yr$
    IF LEN(yr$) <> 7 THEN GOTO yrnot
    yr1 = VAL(MID$(yr$, 3, 2))
    yr2 = VAL(MID$(yr$, 6, 2))
    wage1 = 5.104987 + ((yr1 - 77) * .319739)
    wage2 = 5.104987 + ((yr2 - 77) * .319739)
    wage = (wage1 + wage2) * .5
    LOCATE 7, 9, 0
    PRINT "Extrapolated average wage for year "; yr$; " is $ ";
    PRINT USING "##.##"; wage;
    PRINT " per hour"
    LOCATE 19, 22, 0
    INPUT ; "Do you want to change this (Y/N) ", jb$
    IF jb$ = "Y" OR jb$ = "y" THEN
                  LOCATE 10, 22, 0
                  INPUT "Current Average Wage (in $/hour) = ", wage
    END IF
inflat = wage / 5.26
COLOR 0, 7, 0
LOCATE 23, 12, 0
PRINT " If you want a printout press PRTSC now else press ENTER "
COLOR 7, 0, 0
INPUT ; "", ff$
CLS
COLOR 0, 7, 0
LOCATE 11, 34, 0
PRINT "PLEASE  WAIT "
LOCATE 13, 30, 0
PRINT "Simulating "; NoSimul; " Cars"

END SUB


SUB outscrn (lcost, dcost, segcode$, yr$, bmp, emp)
CLS
LOCATE 1, 33, 0
PRINT "OUTPUT  SCREEN"
LOCATE 3, 30, 0
PRINT "Segment Code         "
```

```
LOCATE 5, 1, 0
PRINT "Beginning Mile Post :        "
LOCATE 5, 50, 0
PRINT "Ending Mile Post :        "
LOCATE 3, 44, 0
PRINT segcode$
LOCATE 5, 23, 0
PRINT USING "###.###"; bmp
LOCATE 5, 69, 0
PRINT USING "###.###"; emp
LOCATE 7, 34, 0
PRINT "YEAR "; yr$
LOCATE 10, 15, 0
PRINT "Cost of delay                 ";
PRINT USING "#######.##"; lcost;
PRINT " $ per day"
LOCATE 12, 15, 0
PRINT "Cost of discomfort            ";
PRINT USING "#######.##"; dcost;
PRINT " $ per day"
LOCATE 14, 15, 0
PRINT "Cost of delay and discomfort  ";
PRINT USING "#######.##"; dcost + lcost;
PRINT " $ per day"
LOCATE 22, 12, 0
COLOR 0, 7, 0
PRINT " If you want a printout press PRTSC now else press ENTER "
COLOR 7, 0, 0
INPUT ; "", kan$
END SUB



SUB scrnl
CLS
LOCATE 8, 24, 0
PRINT "DELAY & DISCOMFORT COST ANALYSIS"
LOCATE 11, 39, 0
PRINT "By"
LOCATE 13, 30, 0
PRINT "Dr. Donald  F. Haber"
LOCATE 14, 40, 0
PRINT "&"
LOCATE 15, 33, 0
PRINT "Umesh  S. Limaye'"
LOCATE 24, 26, 0
PRINT "Press any key to continue..."
DO
LOOP WHILE INKEY$ = ""

END SUB
```

```
SUB scrn2 (segcode$, bmp, emp, lanes, wntadt, work, i$, lsc, lsp, trip)
CLS
LOCATE 1, 30, 0
PRINT "DATA  INPUT  SCREEN"
LOCATE 3, 30, 0
PRINT "Segment Code  ______"
LOCATE 5, 1, 0
PRINT "Beginning Mile Post : ___.___"
LOCATE 5, 50, 0
PRINT "Ending Mile Post : ___.___"
LOCATE 3, 44, 0
INPUT ; "", segcode$
LOCATE 5, 23, 0
INPUT ; "", bmp
LOCATE 5, 69, 0
INPUT ; "", emp
q1:
LOCATE 7, 10, 0
INPUT ; "Is this section of road designated as an INTERSTATE  (Y/N)  ", i$
IF NOT (i$ = "y" OR i$ = "Y" OR i$ = "n" OR i$ = "N") THEN GOTO q1
LOCATE 9, 10, 0
INPUT ; "Number of Lanes  ", lanes
LOCATE 11, 10, 0
INPUT ; "Winter Average Daily Traffic (WNTADT)  ", wntadt
LOCATE 13, 10, 0
INPUT ; "Percentage of WNTADT that is going to work [ e.g 60% ] ", wo$
IF MID$(wo$, 3, 1) = "%" THEN work = VAL(LEFT$(wo$, 2)) ELSE work =
VAL(LEFT$(wo$, 3))
current:
    LOCATE 15, 10, 0
    INPUT ; "Current  Winter Maintenance Standard or Level of Service  ",
lsc
  IF NOT (lsc = 1 OR lsc = 2 OR lsc = 3) THEN GOTO current
proposed:
    LOCATE 17, 10, 0
    INPUT ; "Proposed Winter Maintenance Standard or Level of Service  ",
lsp
  IF NOT (lsc = 1 OR lsc = 2 OR lsc = 3) THEN GOTO proposed
LOCATE 19, 10, 0
INPUT ; "Average Car Trip Length (in miles) ", trip

COLOR 0, 7, 0
LOCATE 23, 12, 0
PRINT " If you want a printout press PRTSC now else press ENTER "
COLOR 7, 0, 0
INPUT ; "", kf$
END SUB
```

APPENDIX H

A FLOPPY DISK CONTAINING EXECUTABLE FILES

APPENDIX I

GLOSSARY OF ACRONYMS/ABBREVIATIONS

Glossary of Acronyms/Abbreviations

ASH - Average daily manhours of snow removal/sanding reported during a storm. A storm was defined as those days for which the number of reported snow-removal/sanding hours exceeded specified cutoff value.

CF - Climatic factor. Derived from climatic region map used for pavement design.

CRCURVE - Factor which describes the critical curves for each road section within each foreman area.

CURVE - Factor which describes the number of curves for each road section within each foreman area.

d TSH - This is an yearly deviation of total storm hours from average of total storm hours taken over time. This is a transient factor.

ELEV - Average elevation of the roadway in each foreman area.

FA - Foreman area.

GRADE - Factor which describes the average maximum grade for the road within a foreman area.

ITD - Idaho Transportation Department.

LS - Level of Service.

N ST - Storm frequency. This is number of times a storm hits a foreman area.

PASSITP - Percentage of a foreman area's total lane-miles which have greater than 1500' safe passing sight distance.

SAS - Statistical Analysis System.

SF - Snow Factor.

SII - Statewide Inflation Index.

SSE - Sum of the squares of the errors.

STOPD - Critical stopping sight distance.

SWP - Severe wind percentage. This is percentage of the total lane-miles in a foreman area, affected severely by the wind drifting.

TAC - Total average cost.

TEMP - Average minimum January temperature for each foreman area.

TERRF - Terrain factor. This is derived from the number of lane-miles classified as Mountainous, Rolling or Flat.

TLM - Total lane-miles.

TSH - Total storm hours. This is number of manhours expended on the storm days during a winter season by a foreman area or a district.

URBANP - Percentage of foreman areas total lane-miles which are classified as urban rather than rural.

WF - Wind Factor.

WNTADT - Winter average daily traffic.